SERDP

DoD EPA DOE

Strategic Environmental Research and Development Program

Improving Mission Readiness Through Environmental Research

ANNUAL REPORT TO CONGRESS
FISCAL YEAR 1997

A REPORT BY

THE COUNCIL

OF THE
STRATEGIC ENVIRONMENTAL RESEARCH
AND DEVELOPMENT PROGRAM

March 1998

SERDP
Strategic Environmental Research and Development Program
Improving Mission Readiness Through Environmental Research

June 18, 1998

Ms. Joyce Chiras
Defense Technical Information Center
DTIC/OCA
Suite 0944
8725 John J. Kingman Road
Ft. Belvoir, VA 22060-6218

Re: Strategic Environmental Research and Development Program (SERDP) Annual Reports to Congress - FY 1997

Dear Ms. Chiras:

Enclosed are copies of the *Annual Report to Congress - FY 1997* by the SERDP Council and the *Annual Report to Congress - FY 1997* by the SERDP Scientific Advisory Board for your use. There is no proprietary information contained within these documents so feel free to make them available to any interested parties. Both reports have also been distributed to the Library of Congress and are available for download from our website (http://www.serdp.gov).

Sincerely,

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ANNUAL REPORT TO CONGRESS– FISCAL YEAR 1997

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AND DEVELOPMENT PROGRAM

March 1998

This document was prepared for the Executive Director, Strategic Environmental Research and Development Program (SERDP) by HydroGeoLogic, Inc. under Contract Number DACA39-98-C-0004. Questions regarding SERDP should be directed to the SERDP Program Office located at 901 North Stuart Street, Suite 303, Arlington VA, 22203.

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PREFACE

The Strategic Environmental Research and Development Program was established by Title 10 U.S.C. §§2901-2904. The Strategic Environmental Research and Development Program (SERDP) addresses environmental matters of concern to the Department of Defense and the Department of Energy. It is a Department of Defense Program planned, managed, and executed in full partnership with the Department of Energy and Environmental Protection Agency with participation by numerous other Federal and non-Federal organizations.

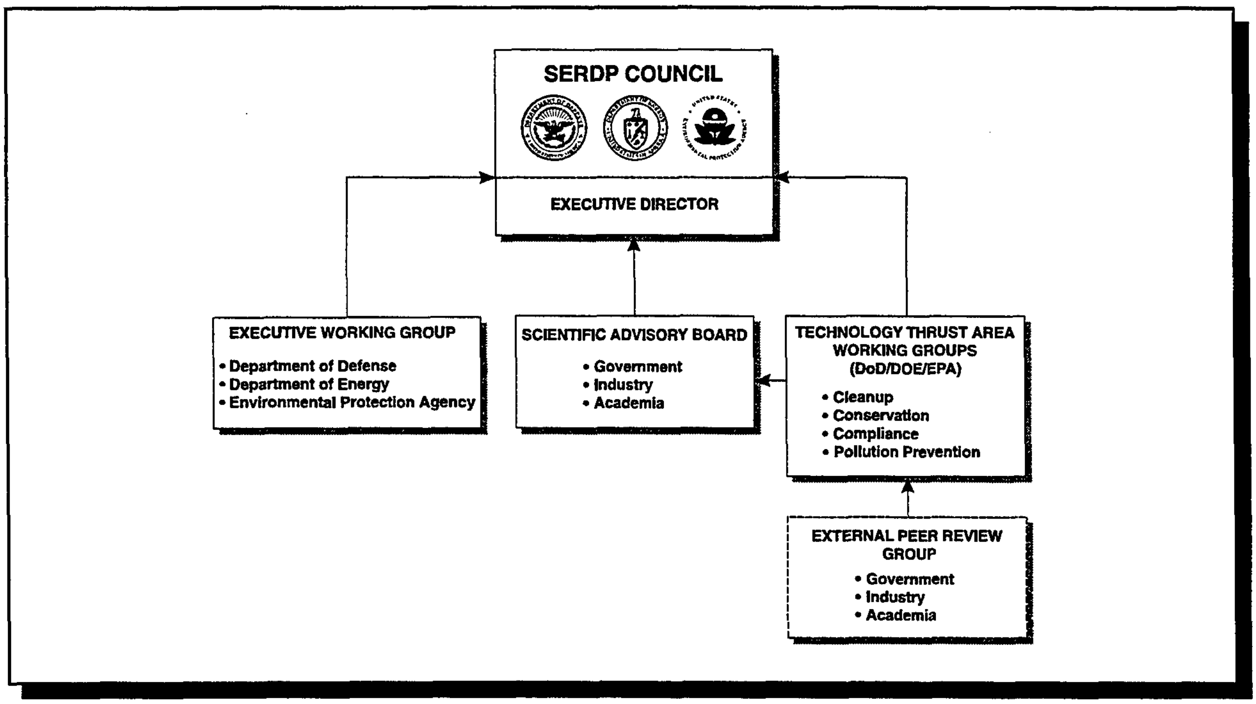


Figure 1 SERDP Organization

This report of the SERDP Council provides a summary of SERDP's activities and most significant accomplishments during fiscal year 1997, its plans for fiscal year 1998, and new initiatives to be addressed in fiscal year 1999.

SERDP Council

Title 10, U.S.C. §2902 established the Strategic Environmental Research and Development Program Council to oversee management of SERDP. Specifically, this Council prescribes policies and procedures to implement the SERDP and may enter into contracts, grants, and other agreements in accordance with other applicable law, to carry out the purposes of SERDP. Congress intended the Council to be a multi-agency membership body to promote maximum exchange of information and to minimize duplication of environmental related research, development, and demonstration activities through close coordination with

the military departments and Defense Agencies, the Department of Energy, the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, other departments and agencies of the Federal Government and State and local governments, and other organizations engaged in environmental related research.

Consistent with the SERDP statute and with facilitating multi-agency cooperation, the Department of Defense designates a member of the Council as chairperson for each odd-numbered fiscal year and the Secretary of Energy designates a member of the Council to serve as chair for each even-numbered year.

Council Members

Mr. Alvin Alm
Department of Energy
Environmental Management

Dr. Richard Chait
Department of the Army
Research, Development and Acquisition

Colonel Joseph Corcoran
Department of Defense
Joint Chiefs of Staff

Colonel Richard Drawbaugh
Department of the Air Force
Environment, Safety, and Occupational Health

Ms. Sherri Goodman
Department of Defense
Environmental Security

Dr. John Harrison
(Replaced by Mr. Smith)
Strategic Environmental Research and Development Program

Dr. Robert Huggett
(Replaced by Mr. Longest)
Environmental Protection Agency Research and Development

Dr. Anita Jones (Chair)
(Replaced by Mr. Singley)
Department of Defense
Research and Engineering

Dr. Martha Krebs (Alternate Chair)
Department of Energy
Energy Research

Mr. Henry Longest, II
(Replaced Dr. Huggett)
Environmental Protection Agency
Research and Development

Dr. Victor Reis
Department of Energy
Defense Programs

Dr. Fred Saalfeld
Department of the Navy
Naval Research

Mr. George Singley, III (Chair)
(Replaced Dr. Jones)
Department of Defense
Research and Engineering

Mr. Bradley Smith
(Replaced Dr. Harrison)
Strategic Environmental Research and Development Program

Captain Gary Steinfort
U.S. Coast Guard
Research and Development

SERDP Scientific Advisory Board

The SERDP Scientific Advisory Board (SAB), established in accordance with the SERDP statute, assures the Council's primary focus on technical quality. The SAB may make recommendations to the Council regarding technologies, research, projects, programs, activities, and, if appropriate, funding within the scope of the SERDP.

The SAB is composed of no more than 14 members who are jointly appointed by the Secretary of Defense and the Secretary of Energy in consultation with the Administrator of the Environmental Protection Agency. Fourteen members served on the Board during the year, although the year ended with thirteen members. To assure a program that is congruent with the Administration's goals, the Science Advisor to the President (or his designee) is a statutory member of the SAB. Similarly, the Administrator of the National Oceanic and Atmospheric Administration, or his designee, is a statutory SAB member to ensure that regional and global environmental issues are appropriately addressed in SERDP.

The *Annual Report to Congress-Fiscal Year 1997* by the SERDP SAB reviews the specific actions taken and recommendations made by the SAB during fiscal year 1997. The report was provided to Congress in March 1998.

Scientific Advisory Board Members

Dr. Rosina M. Bierbaum
Office of the Science Advisor to the President

Mr. Richard A. Carpenter
Environmental Consultant

Mr. Richard A. Conway
Union Carbide Corporation

Mr. Amos S. Eno (Vice Chair)
National Fish & Wildlife Foundation

Dr. Raymond C. Loehr
University of Texas at Austin

Dr. Marvin K. Moss
University of North Carolina at Wilmington

Dr. Frank L. Parker
Vanderbilt University

Dr. Michael J. Ryan
Bechtel Environmental, Inc.

Dr. Jean'ne M. Shreeve
University of Idaho

Dr. Lydia W. Thomas
The Mitretek Systems, Inc.

Dr. Walter J. Weber, Jr. (Chair)
University of Michigan

Dr. Karen E. Wetterhahn(†)
Dartmouth College

Mr. Robert S. Winokur
National Oceanic and Atmospheric Administration

Mr. Randolph Wood
Nebraska Department of Environmental Quality

† -Deceased.

I. OVERVIEW

Introduction

As the Department of Defense's (DoD) corporate environmental Science and Technology (S&T) program, the Strategic Environmental Research and Development Program (SERDP) remains dedicated to solving DoD environmental problems by providing a forum for environmental technology partnership. It fully leverages complementary programs found within the Army, Navy, and Air Force, as well as those of the Department of Energy (DOE) and the Environmental Protection Agency (EPA). The SERDP Council has implemented policies that take full advantage of the intrinsic capabilities of the participating organizations and has guided the development and execution of the Program consistent with the SERDP authorizing statute.

SERDP is a "requirement-driven" program; the research conducted directly responds to defense requirements generated by the Services and sanctioned by the Deputy Under Secretary of Defense for Environmental Security (DUSD/ES). DoD environmental concerns may be divided into two broad categories: those that impact training, logistics, and combat operations; and those that have cost and performance impacts on the supporting infrastructure. In either case, these concerns can have negative impacts on the Department's ability to perform its primary mission of maintaining military readiness for national defense. SERDP strives to minimize or eliminate major negative impacts of environmental concerns or requirements on DoD's ability to conduct this mission. Current DoD costs of environmental compliance, cleanup, and conservation are significant. Development and application of innovative environmental technologies will reduce costs, environmental risks, and/or time required to resolve environmental problems in these areas while simultaneously enhancing safety and health. Equally important, the development and application of innovative pollution prevention technologies serves to reduce or eliminate waste problems before they occur.

Thus, SERDP is improving mission readiness through environmental research by:

- ✔ Accelerating cost-effective cleanup of contaminated defense sites;
- ✔ Facilitating full compliance with environmental laws and regulations at reduced cost;
- ✔ Enhancing training, testing, and operational readiness through prudent land management and conservation measures; and
- ✔ Reducing or eliminating defense industrial waste streams through aggressive pollution prevention.

SERDP Mission

The mission of SERDP can be found in its authorizing congressional language. Specifically, the Congress established SERDP in Public Law 101-510 (Title 10, U.S.C., §§2901-2904) as a DoD program planned

and executed in partnership with DOE and the Environmental Protection Agency (EPA) to:

- Address environmental matters of concern to the DoD and the DOE through support for basic and applied research and development of technologies that can enhance the capabilities of the departments to meet their environmental obligations;

- Identify research, technologies, and other information developed by the DoD and the DOE for national defense purposes that would be useful to governmental and private organizations involved in the development of energy technologies and of technologies to address environmental restoration, waste minimization, hazardous waste substitution, and other environmental concerns, and to share such research, technologies, and other information with such governmental and private organizations;

- Furnish other governmental organizations and private organizations with data, enhanced data collection capabilities, and enhanced analytical capabilities for use by such organizations in the conduct of environmental research; and

- Identify technologies developed by the private sector that are useful for DoD and DOE defense activities concerning environmental restoration, hazardous and solid waste minimization and prevention, and hazardous material substitution, and provide for the use of such technologies in the conduct of such activities.

The basic statute and congressional intent have remained the same since 1991. While FY 1997 legislation makes no major program changes, it does address specific Scientific Advisory Board procedures regarding terms of membership. Membership on the Board was revised to provide for terms of two to four years to enhance flexibility in maintaining a maximum of 14 members. Additionally, two Congressionally appropriated projects were added to the program for FY 1997 and were specifically aimed to enhance research and development in the area of Insensitive Munitions and in support of the National Environmental Education and Training Center (NEETC). Descriptions of these efforts may be found in Appendix D and Appendix B, respectively.

Program Goals

In the course of addressing DoD's highest priority environmental needs in the areas of Cleanup, Compliance, Conservation, and Pollution Prevention, SERDP also has sought opportunities to help solve other significant national and international environmental problems through the application of DoD's technical capabilities, analytical systems, and information.

SERDP's goals, as prescribed by the SERDP Council:

- Resolve environmental concerns in ways that enhance military operations, improve military systems' effectiveness, and help ensure the safety of personnel; and

- Support technology and process development that reduce operational and life-cycle costs, including those associated with environmental cleanup and costs of full compliance with environmental laws and regulations.

SERDP has achieved its goals through the following methods:

- Identifying and supporting programs of basic and applied research and development to:
  - facilitate environmental compliance, remediation, and conservation activities;
  - minimize waste generation, including reduction at the source; and
  - substitute use of non-hazardous, non-toxic, non-polluting, and other environmentally sound materials, substances, and processes;

- Promoting the effective exchange of information regarding environmentally related research and development activities;

- Ensuring that SERDP research and development (R&D) activities complement, but do not duplicate, Tri-Service R&D programs and other ongoing activities;

- Providing appropriate access to data under the control of, or otherwise available to, the Departments of Defense and Energy that is relevant to environmental matters;

- Facilitating the transfer of unclassified DoD and DOE environmental information and technology to other sectors of society which might be able to use them to advance national environmental objectives; and

- Emphasizing multi-service, inter-departmental research and development projects and using the unique capabilities of the partnering Federal agencies, private industry, and academia to solve the Departments' environmental problems.

Program Management and Oversight

One of the strengths of SERDP is the multi-agency management and oversight of the program. Membership of the SERDP Council, Executive Working Group (EWG), and Technology Thrust Area Working Groups (TTAWG) consists of programmatic and technical individuals that represent the three primary participating organizations. This arrangement brings with it a breadth of knowledge and experience at several levels of management and technical expertise which significantly lends credibility to the Program.

Knowledgeable individuals from DOE's Environmental Management technology development programs and EPA's SITE projects are represented in the same force along with the principal representatives of the defense user community. Similarly, many of the DoD representatives on the TTAWGs also serve on the DoD Joint Engineers Management Panel team and provide insight to the technology roadmaps being planned within DoD inter-Service Reliance agreements. Collectively, these mutual benefits result in a well-coordinated, leveraged program that reduces duplication of effort within the Federal R&D infrastructure.

Council Actions

On September 19, 1996, the SERDP Council approved the FY 1997 Program Plan and the FY 1998 Strategic Guidance and expressed their desire to include broader participation from the non-Federal sector in addition to the Federal partners. The SERDP FY 1997 appropriation remained essentially unchanged from the FY 1996 levels ($54.4 million to $54.9 million).

At the behest of the SERDP Council Chair (Director, Defense Research and Engineering), SERDP began solicitating direct participation of academia and private industry in the call for proposals for FY 1998 New Start projects through a Broad Agency Announcement (BAA). This process fulfilled the Council's expectations to embrace the widest possible competition, further enhance the quality of SERDP research and development projects, and help foster public-private environmental partnerships.

The SERDP Council met again one year later on September 26, 1997, to approve the FY 1998 Program, FY 1999 Strategic Guidance, and the FY 1999 Investment Plan. They reiterated continued emphasis on refocusing the Program to address the highest priority, Defense mission-relevant environmental requirements in the four major DoD environmental Thrust Areas of Cleanup, Compliance, Conservation, and Pollution Prevention as defined by the Deputy Under Secretary of Defense for Environmental Security. In view of a stabilized SERDP Program in terms of both funding and research directions, the SERDP Executive Director requested the Council to approve a 'standing' Strategic Guidance document to which the Council agreed. The focus area needs will be addressed separately, annually, and will be presented to the Council as annual Statement of Needs.

The Council also reviewed the results of the FY 1998 solicitation process including a summary of projects awarded to both Federal and private organizations. Only 12 of the 22 SONs were made available to the non-Federal sector for proposal. The FY98 BAA and Federal solicitation resulted in 486 proposals and preproposals in response to the 22 statements of need (SON). Overall, the Federal sector submitted 32 percent of the proposals, 31 percent were received from industry, and 37 percent were forwarded from academia. For FY 1998, out of total $13.9 million that has been provided for the New Start efforts, approximately $5.2 million was awarded to the non-government performers. The Council acknowledged the successful implementation and benefits of SERDP's FY 1998 non-Federal participation pilot program. To ensure effective non-Federal participation and return on investment in the future, the Council established a goal of a 20 percent award rate for private-sector proposals for the FY 1999 solicitation. Figure I-1 depicts the distribution of proposals selected during the FY 1998 program development process.

The SERDP Council anticipates final review and approval of the FY 1999 Program in September 1998.

Thrust Area	No. of Statements Selected	No. of Proposals Selected	SOURCE Federal	Academia	Private	Approximate Value (Thrust Total)
Cleanup	**4**	**8**	**5**	**0**	**3**	**$4.0 million**
Compliance	**5**	**8**	**4**	**3**	**1**	**$2.9 million**
Conservation	**6**	**11**	**5**	**6**	**0**	**$3.5 million**
Pollution Prevention	**7***	**8**	**5**	**0**	**3**	**$3.5 million**
Total	22	35	19	9	7	$13.9 million

***One Statement of Need was canceled due to lack of response.**

Figure I-1. FY 1998 Proposal Distribution By Thrust Area

Executive Director Actions

Keys to Success

The SERDP Executive Director, with the Council's direction, carried out the FY 1997 program and FY 1998 program development activities. Focus on the following four key metrics continued in order to enhance the success of the Program.

1) Address the highest-priority, Defense mission-relevant environmental requirements with emphasis on multi-service issues.

The Executive Director and his Program Managers worked hand-in-hand with ODUSD(ES) to establish clear lines of communication, address effectively the Department's highest priority environmental requirements, and foster transition of technical efforts to field demonstration or implementation. Acting on the advice of the SERDP Council and the Scientific Advisory Board to embrace widest competition in the selection of the proposals for FY 1998, the Executive Director opened the SERDP solicitation process to the non-Federal sector. Through the use of tailored Statements of Need (SON), the Executive Director solicited cooperatively funded and executed projects to address high-priority multi-service needs. The TTAWGs, SERDP's multi-agency planning and coordinating bodies, facilitated this process by communicating effectively and applying their knowledge of the needs and capabilities of the Federal R&D infrastructure.

2) Pursue/achieve universal, world-class technical excellence.

World-class research is considered the cornerstone of SERDP projects. Beginning with the development of the FY 1998 Program, SERDP added an external Peer Review Process to the existing comprehensive review procedures assuring that technically sound proposals performed by world-class researchers are selected for funding. Technical experts representing universities, industry, and government participate in the Peer Review Process. Additionally, the SAB, TTAWGs and the Executive Director all emphasize and

ensure that each research team demonstrates superior technical merit and performs according to world-class research standards.

As an example of SERDP's search for world-class technical excellence, SERDP sponsored a management scale ecosystem workshop in the spring of 1997. The objective of the workshop was to initiate a process to define some of the critical deficiencies of fundamental ecological science and identify research needs and opportunities to provide a stronger scientific basis for effective ecosystem management of Defense installations. The workshop convened a prestigious group of ecologists, scientists from related disciplines, land managers, and regulators to determine the areas of opportunities to conduct research in support of Defense requirements. The results of this effort have provided a scientific foundation upon which to build an integrated ecosystem management research initiative.

3) Emphasize Technology Transfer.

The SERDP Executive Director and the Program Managers aggressively emphasized transfer of SERDP sponsored research results to the Defense users and/or the next steps of development, demonstration, or commercialization. Additionally, the SERDP Program Office and the Environmental Security Technology Certification Program (ESTCP) Office will be co-located, and the ESTCP Director will serve additionally as the Technical Director of SERDP. ESTCP is the DoD's demonstration/validation vehicle to foster further development, transition, and deployment of promising environmental technologies that have demonstrated proof-of-principle. Co-locating these two Program Offices will provide DoD with a well-coordinated corporate 6.1 (Basic Research) through 6.4 (Demonstration/Validation) environmental research and development management structure. This relationship will foster excellent coordination and successful transition of research and development projects to the users.

Additionally, during the annual In-Progress Reviews in May 1997, the Principal Investigators (PI) of all SERDP projects were required to demonstrate their interaction with the user community or those who will sponsor further development. Members of the multi-agency TTAWGs, Joint Engineers Management Panel (JEMP) members, and key representatives from ODUSD(ES) were in attendance and provided various potential technology transfer opportunities to the PIs. The annual SERDP Symposium held in December 1997 provided an excellent technology transfer and networking forum for the SERDP Principal Investigators. This symposium will continue to serve as a significant, annual technology transfer event.

4) Ensure Sound Fiscal Management.

Timely and complete financial reporting is one of the principal keys to SERDP's success. After accelerating the SERDP Program in FY 1996 to release the appropriations on a budget cycle for the first time, the SERDP Executive Director continued to ensure that the FY 1997 program complied with the DoD fiscal guidance. Effective controls included periodic fiscal review of projects, implementing aggressive corrective actions to promote effective use of scarce R&D resources, and implementation of various monitoring tools such as the Automated Information System, and the monthly financial reporting (MFR) system. This new MFR system allows the Principal Investigators to submit their obligations and expenditure summary via the SERDP Home Page on the Internet.

Technology Transfer

Transfer of technology, from research to the DoD environmental user community, is a key objective of SERDP. This overall program objective is achieved by supporting applied research and technology demonstrations that respond directly to high-priority DoD mission related environmental needs. Now nearing completion of its sixth year of technology development, SERDP is aggressively pursuing technology transfer mechanisms. Many of the projects initiated in the earlier years are being completed and are now ready for implementation or transition to the next step of development.

One significant technology transfer tool for SERDP is the annual Symposium. SERDP planned, coordinated, and held its third annual Symposium from December 3-5, 1997, in Washington, DC. The theme for this year's Symposium was "Partners in Environmental Technology". This event was co-sponsored by DoD Environmental Security Technology Certification Program (ESTCP) and included speakers/poster presentations from government, academia, and industry. Among this year's 438 participants, approximately one-half were first time attendees. SERDP embarked on a new technical format at this Symposium that included 11 high-priority topics of interest to the defense community. Additionally, a new summary session on SERDP/ESTCP was included that explained program development, process, and future opportunities. This Symposium encouraged partnering, contained more than 90 posters and display exhibits, and provided an outstanding forum for exchange of latest Defense mission-relevant environmental technology information and ideas. Next year's Symposium is scheduled from Dec. 1-3, 1998, in the Washington DC area and promises to be an equally successful event.

SERDP management has taken major steps to facilitate and enhance information transfer. A formal SERDP display was exhibited at several national environmental conferences including National Marketplace for the Environment, the annual American Defense Preparedness Association (ADPA) Environmental Conference, the Tri-Service Environmental Technology Conference, and the ADPA Joint Service Pollution Prevention Conference. Capitalizing on the successes of the Ecosystems Management Workshop in FY 1997, the Executive Director, at the recommendation of the SERDP SAB, initiated plans to conduct a cleanup workshop that focuses on environmentally acceptable endpoints for remediation.

The SERDP Home Page (http://www.hgl.com/SERDP/) allows users of the Internet to become familiar with SERDP goals and objectives, technical areas of interest, planning calendars, performers, management structure, and program results. For the first time, the BAA announcement for the FY 1998 SERDP Proposal Solicitation process was posted on SERDP's home page and generated more than 2000 "hits." Recent additions to the Home Page include an updated list of SERDP research products; technology area summary data; Program updates; and an updated list of SERDP performers with associated hypertext information links to describe the work being performed at various locations.

The SERDP Quarterly Information Bulletin distribution significantly increased from 4,000 to 6,000 people at all levels of the private and governmental sectors. The Bulletin features SERDP accomplishments, success stories, articles on SERDP initiatives, and highlights of Program development issues. A summary of the FY 1998 proposal solicitation process and highlights from SERDP sponsored ecosystem research workshop were included in the July 1997 Bulletin. Archived SERDP Quarterly Information Bulletins are available on the SERDP Home Page.

Management Plans for FY 1998

With the co-location of the SERDP and ESTCP Program Offices, significant management improvements and changes are imminent for FY 1998. The ESTCP Director will now assume additional responsibility as SERDP Technical Director and further strengthen the management team.

Major SERDP events planned for FY 1998 are described below.

- Continue direct non-Federal sector participation via Broad Agency Announcements for the solicitation of FY 1999 proposals and continuation of an external peer review process for evaluating FY 1999 proposals received from both the Federal and non-Federal sectors;

- For the first time, conduct the annual In-Progress Reviews in conjunction with the ESTCP, focusing on technical progress, technology transfer plans, and fiscal management;

- At the recommendation of the SERDP Scientific Advisory Board, conduct a Cleanup Workshop in early summer 1998 to address research into environmentally acceptable endpoints for remediation at military sites and include participation of the American Academy of Environmental Engineers. This initiative is expected to help focus research efforts on high potential payoff opportunities in the Cleanup area.

- Conduct the annual Symposium, focusing on technology transfer and increasing awareness of SERDP and SERDP-related efforts within the DoD user community.

Program Technical Strategy

For FY 1997, the SERDP Council directed the continuing pursuit of six avenues in planning and executing defense mission-relevant environmental R&D.

✔ Identify and fund major-impact, multi-agency environmental R&D programs to solve high-priority, mission readiness related concerns of DoD;

✔ Identify opportunities to accelerate existing DoD environmental quality R&D programs and fund those that address the highest priority concerns of the Department;

✔ Identify, leverage, adapt, and/or adopt existing technologies to address environmental concerns of DoD and DOE;

✔ Advance and use applicable state-of-the-art modeling and simulation capabilities to accomplish SERDP goals;

✔ Use the technical and research capabilities of the SERDP partners, including their unique

data collection and analysis capabilities, as appropriate; and

✔ Plan for a transition of successfully proven technologies to demonstration and validation or to commercialization and implementation.

The SERDP Scientific Advisory Board (SAB), in their reaffirmation that SERDP be proactive and visionary as opposed to reactive, discussed the meaning of 'strategic' as it relates to the Program. Each and every project was reviewed during this fiscal year in the context of the defined characteristics that are associated with a 'strategic' defense R&D program. Specifically, the SAB emphasized that SERDP should focus on research that is (1) essential for the solution of major defense mission-readiness related problems; (2) scientifically plausible; (3) focused on areas where progress under other program sponsorship in DoD and/or other agencies is not sufficient or satisfactory; (4) catalytic in nature to initiate, organize, and accelerate essential research in partnership with the Federal and private sector; and (5) certain to provide sufficient proof of principle demonstrations to attract follow-on Research Development Test & Engineering (RDT&E) support.

Research Framework

The research taxonomy that was used in FY 1997 to define the SERDP Program is provided in Figure I-2.

CLEANUP	COMPLIANCE	CONSERVATION	POLLUTION PREVENTION
Site Characterization and Monitoring	Air	Maintain/Enhance Training/Testing Capability	Air
	Water		Water
Remediation Technologies	Solid	Natural Resource Stewardship	Solid
	Noise		Modeling & Databases
Risk Assessment Technologies		Cultural Resource Stewardship	

Figure I-2. Research Areas

As the DoD's corporate environmental R&D program, the SERDP primary Thrust Areas are a result of the user community needs for science and technology required to accomplish the military mission in an environmentally compliant manner. Accordingly, these Thrust Areas - Cleanup, Compliance, Conservation and Pollution Prevention - are consistent with the focus of the Office of the Deputy Under Secretary of Defense for Environmental Security and they directly parallel the four pillars of the Tri-Service Environmental Quality Technology programs. The Thrust Areas also correspond to those identified in the National Environmental Technology Strategy.

SERDP leverages and interacts with other environmental programs to identify and solve defense specific needs, extend applications of defense information to others, and build on existing science and technology to derive more useable and cost-effective approaches for achieving reductions in environmental risks. The efforts collectively facilitate acceptance by Defense Systems Program Executive Officers (PEOs) and transition to the commercial sector. Figure I-3 illustrates SERDP's role in the environmental technology development process.

In the past, SERDP projects have depended on the Services' Environmental Quality Technology Programs, higher development programs, and the Environmental Security Technology Certification Program (ESTCP) to capture S&T research and transition these products to the field. The co-location of ESTCP with SERDP

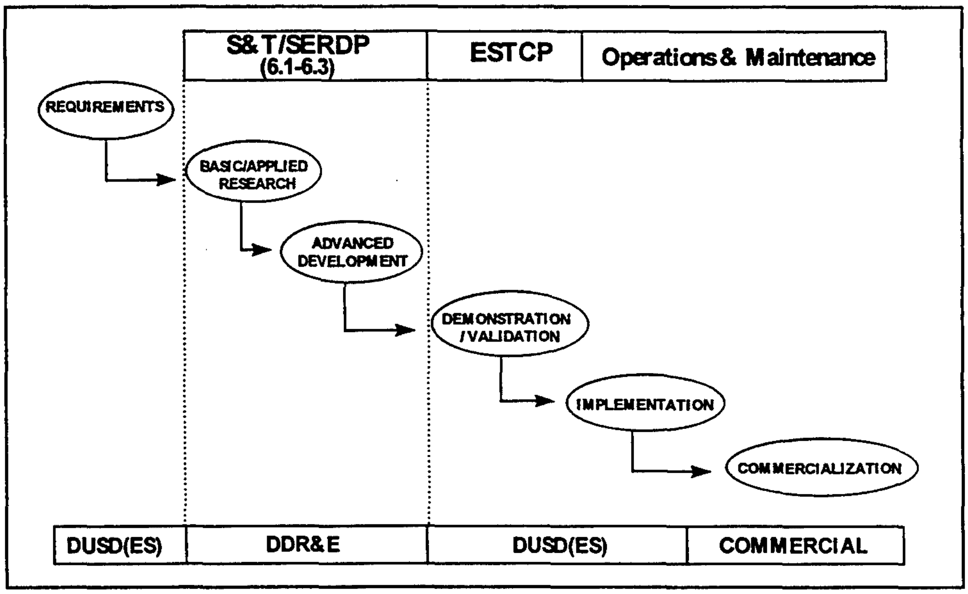


Figure I-3. Environmental Technology Development Process

is a major step forward toward ensuring a close cooperation between research and development projects and the actual demonstration of environmental technology to the users in the field.

Additionally, throughout the year, SERDP has interacted with Program participants to effect information transfer regarding the capabilities and ongoing programs that are relevant to SERDP activities.

Information Transfer Vehicles

- Workshops to develop the multi-services research needs and prioritization of these needs.
- Direct participation by industry and academia in the solicitation of proposals for the New Start projects.
- Technology transfer and exchange of R&D results at the SERDP Annual Symposium. The theme of FY 1997 SERDP Symposium held in Washington, DC, from December 3-5, 1997, was "Partners in Environmental Technology." More than 435 environmental scientists and professionals attended this event.
- Briefings to the Scientific Advisory Board from DoD, DOE, and EPA Programs.
- Project briefings to SERDP management during the annual In-Progress Review.
- Participation at the annual DoD Environmental Technology Area Review & Assessment (TARA) review.
- Website to disseminate program results, activities, schedules, and other useful information.
- Participation in environmentally related conferences and workshops.

During FY 1997, SERDP also introduced the use of an external independent Peer Review Process to evaluate technically FY 1998 proposals as part of the FY 1998 Program development process. Peer review is considered to be an integral part of any credible evaluation process, and the SERDP SAB and Council were pleased with the peer review procedures established by SERDP and endorsed the process for future years.

Investment Strategy

The SERDP Council annually determines the distribution of funding to the Thrust Areas. Figure I-4 depicts the percentage of Program funding trends for each technology Thrust Area from FY 1997 through FY 2002.

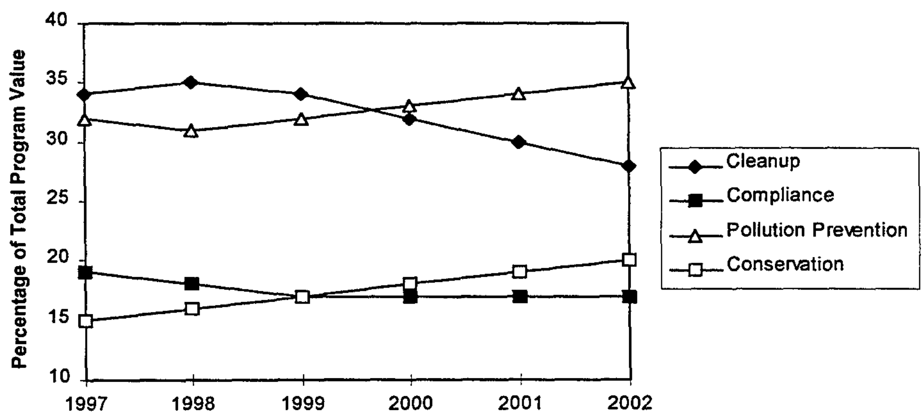


Figure I-4. Funding Balance Across the SERDP Thrust Areas

Forecasts are based on known or expected requirements and stated goals of the Services and ODUSD(ES). Requirements for R&D may change from year to year; consequently, these trends may not reflect actual investments.

DoD has set specific Cleanup goals for completion in the future. Accordingly, in order to impact these goals, technologies currently under development must be delivered to the field in the near future. Hence, the investment in Cleanup is expected to decrease over the next five years. This is part of the conscientious shift within the DoD from a cleanup posture to one of preventing pollution.

A focused investment to eliminate future waste streams will reduce sharply or preclude the environmental consequences experienced in the past. Clearly the biggest returns in the future are expected by reducing or eliminating generation of pollutants. Accordingly, an increase in Pollution Prevention technology investment is anticipated over the next five years.

Current environmental regulations often preclude, or severely restrict, military training, operations, and manufacturing activities, if they are not in total compliance. The current regulatory environment has been relatively stable in recent years. A commensurate slight decrease of effort in SERDP's Compliance investment is anticipated based on the shift from end-of-pipe treatment to pollution prevention; however, this could change with a reinvigorated environmental regulatory agenda.

Conservation technologies have the potential to have the greatest impact on the readiness of military units. Research results from this area will help to resolve legal stalemates and promote environmentally sound land use management. Accordingly, investments in Conservation efforts are anticipated to increase as research efforts mature to demonstration.

Areas of Opportunity

Consistent with past practice, the SERDP Executive Director solicited the advice of the SAB regarding his proposed allocation of funds for the coming year, in this case, the FY 1998 Program. Board members deliberated the merits of the proposed allocations and concluded the following.

- The SAB agreed with the general trends of investment within each of the four Thrust Areas.
- Although they agreed that Cleanup should decline over the course of the next few years, it should decline at a lesser rate than proposed by the Executive Director.
- Similarly, while in agreement that Pollution Prevention is the way of the future, the level of investment should increase at a rate lower than the proposed rate.
- Finally, the SAB advised that investments in Conservation can result in quality opportunities for research and potentially high returns.

Accordingly, the SAB recommended a modified investment strategy that supported modest increases in Pollution Prevention and Conservation investments at the expense of a modest decrease in Cleanup investment.

Summary

FY 1997 marked a special period for SERDP and was distinguished as a year of several firsts. Approximately one-half of the FY98 Statements of Need were open to the private sector through the Broad Agency Announcement; an external Peer Review Process was implemented to ensure the highest technical quality; and the SONs were posted on the SERDP Home Page and generated significant interest with the research and development community. Initial plans for FY 1998 include merging the ESTCP Program Office with the SERDP Program Office, thereby providing a natural conduit for technology transfer.

Under limited budget resources, SERDP continued to maintain focus on the highest-priority Defense environmental needs and program quality and demonstrated successes on many fronts such as successful direct participation of the non-Federal sector during the proposal solicitation process. The SERDP Symposium, held in cooperation with ESTCP, marked true partnering with non-Federal and other Federal programs. The SERDP-sponsored Management Scale Ecosystem Workshop is paving the way for development of knowledge and models needed for effective land management. Numerous SERDP projects that began in FY 1994 and 1995 culminated with successful transition to various demonstration/validation programs or direct implementation within DoD and DOE. The Council's commitment to the four SERDP Keys to Success as well as continued support from the Congress will ensure an aggressive, technology-based, and efficient Program to address this nation's environmental concerns, especially those of specific importance to the DoD.

II. SIGNIFICANT ACCOMPLISHMENTS

Introduction

SERDP plays a pivotal role in the development of science and technology that supports the Department of Defense's environmental security goals. Responding to DoD's highest priority requirements, SERDP has supported more than 225 environmental science and technology projects since its inception in 1991. These projects have enabled DoD installations to meet their environmental responsibilities in cost-effective and innovative ways. A number of SERDP's most significant accomplishments during the past year are described below. While these projects represent just a small selection of the many innovative and ground-breaking projects supported by SERDP, they illustrate the breath and depth of the Program. Furthermore, these accomplishments demonstrate the potential enormous cost savings that will be realized when new technologies become fully implemented. Appendices A through D provide detailed information on each SERDP project.

Cleanup Accomplishments

UXO

Unexploded ordnance (UXO) has emerged as one of DoD's most pressing environmental cleanup problems. UXO presents a threat to active military installations seeking to manage and clean their test and training ranges, as well as to sites designated for base realignment and closure (BRAC), and to formerly used defense sites (FUDS). In the United States alone, current estimates indicate that more than 900 sites (11 million acres) of land of varying terrain, foliation, and topography (including 50 underwater sites) are potentially contaminated with UXO. Using current technologies, the cost of identifying and disposing of UXO in the U.S. is estimated to range up to $500 billion. New technologies capable of detecting UXO with high detection rates and low false alarm rates are required to reduce drastically the cost of a site cleanup by reducing the number of "empty" holes that are excavated. SERDP is pursuing these new technologies through seven projects including three New Starts in FY 1998. Figure II-1 depicts typical UXO that the researchers expect to encounter.

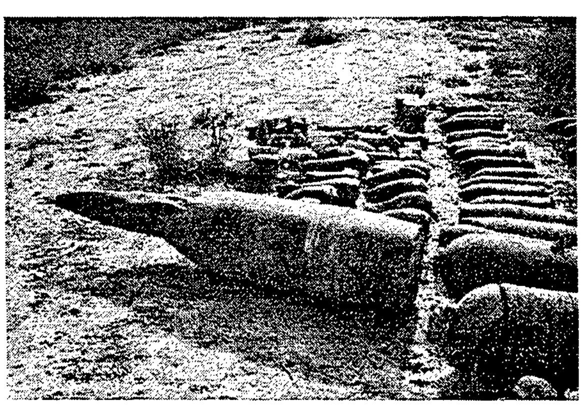


Figure II-1. Typical UXO to be Detected by SERDP Projects

To address the need to remediate underwater UXO, SERDP funded the **Mobile Underwater Debris Survey System (MUDSS) Program (CU-52)**. The MUDSS program demonstrates multi-sensor technologies for the economical, rapid survey of underwater sites for UXO. MUDSS is a joint U.S. Navy and NASA effort executed by the Naval Surface Warfare Center (NSWC) and the Jet Propulsion Laboratory (JPL). A prototype MUDSS sensor system, which outperforms any commercial off-the-shelf (COTS) system, was tested in FY96 and demonstrated the feasibility of using high-resolution

synthetic aperture sonars, a highly-sensitive superconducting magnetic gradiometer, an electro-optic sensor, a chemical sensor and a laser line scanner for detecting and locating underwater UXO targets. In FY97, the MUDSS team, with the assistance of the Canadian Fleet Diving Unit Atlantic, collected sediment samples close to UXO targets in Bedford Basin, Halifax, Nova Scotia, for chemical analysis. Trace amounts of explosives were detected from intact UXO that had been submerged for more than 50 years. This showed the feasibility of using chemical sensing to assist in classifying objects that are difficult to identify optically because they are corroded, obscured by marine growth, or buried. The MUDSS project now is preparing for a final technology demonstration in FY98. MUDSS will reduce the cost of surveying underwater UXO sites by a factor of 10 to 100 as compared to traditional diver-based surveys. A MUDSS detection platform, as illustrated in Figure II-2, also has potential application for surveying sites for environmental cleanup (where the targets are oil drums, toxic waste containers, etc.) and for surveying underwater archaeological sites.

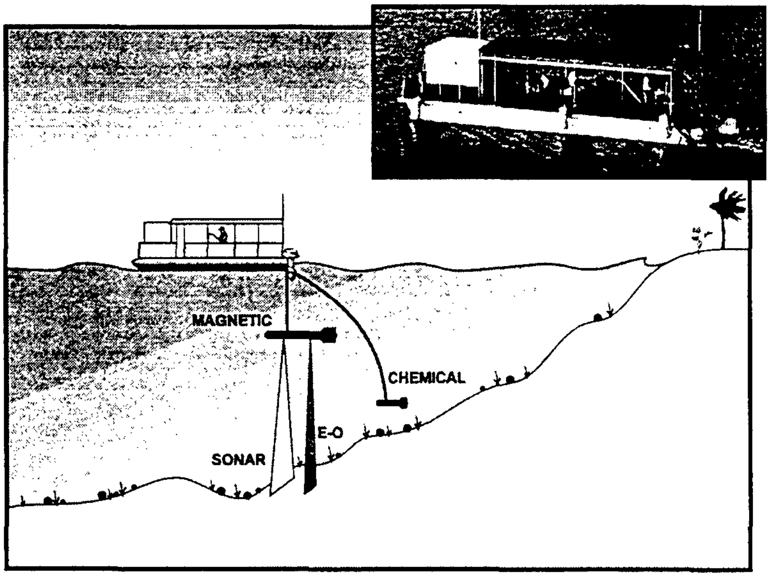


Figure II-2. The MUDSS Platform Addresses the Need to Remediate Underwater UXO

SERDP funded two FY97 New Starts to assess the ability of non-traditional sensors to detect and discriminate UXO from the background clutter. One such project, **Low-Frequency, Ultra-Wideband Boom Synthetic Aperture Radar (Boom-SAR) for Remote Detection of Unexploded Ordnance (CU-1070)**, used its low-frequency, ultra-wideband (50 MHZ - 1200 MHZ) SAR operating from heights of up to 150 feet atop a mobile boom platform as a side-looking ground-penetrating radar to detect buried targets down to several feet below the surface. Results of preliminary investigations concluded that the radar image texture and frequency-dependent scattering from some UXO targets could be exploited in the development of automatic target detection algorithms.

In a complementary New Start project, **UXO Detection by Enhanced Harmonic Radar (CU-1071)** uses a third harmonic SAR to determine its efficiency in not only detecting shallow UXO but in discriminating UXO from other non-UXO objects. In FY97, this project completed an initial proof-of-concept demonstration including the successful detection and characterization of third harmonic signatures from representative UXO samples inside a wooden box filled with sand within an anechoic chamber.

Energetic Materials

The Department of Defense (DoD) has more than 1,200 sites that are contaminated with explosives or energetic materials, and 87 percent of these exhibit contamination in the groundwater. Remediation of

munition sites contaminated with energetic materials and monitoring of the surrounding area represents a primary driver of SERDP-funded research efforts. Effective and efficient remediation requires accurate analyses of field samples. Existing methods require sending a sample to an off-site laboratory for analysis; a process which is time consuming and costly. Recent advances in antibody technology have allowed the introduction of immunoassay techniques to environmental monitoring in the field.

Figure II-3. Portable Device Developed by NRL to Improve On-Site Detection of Explosives

Rapid Detection of Explosives and Other Pollutants (CU-28), employs a biosensor for explosives to test soil and water samples. Operating parameters for selected explosive compounds, including detection limits, possible interferents, and useful system lifetime have been investigated. Following successful laboratory studies in the initial years of the project, researchers performed on-site analyses of environmental samples, including soil and groundwater, to detect and quantify the explosives TNT and RDX. The result is a portable device for field analysis of samples illustrated in Figure II-3. The field trial was conducted at the Louisiana Army Ammunition Depot which demonstrated the low-end detection capability, with detection limits for TNT and RDX in the low parts per trillion, well below current field methods and equal to the most advanced analytical laboratory instrumentation. In addition to being very accurate, this technology provides results in a matter of minutes versus days or weeks and costs a tenth of traditional laboratory analysis.

There is little current toxicological and exposure information regarding TNT and its by-products, e.g., Trinitro Benzene (TNB). As a result, DoD has been unable, in the past, to either refute or confirm whether or not the current required regulatory cleanup levels impose any risk to wildlife and ecosystem health. The **Ecological Biomarkers: Monitoring Wild Fauna at DoD Installations (CS-244)** project developed risk analysis and assessment techniques and toxicity methodologies to assess the validity of these cleanup goals. The results indicated that the currently acceptable cleanup level of 0.96 ppm for TNB may be raised by as much as 600 fold without any risk to the wildlife and ecosystem health. For DoD's 2000 munitions contaminated sites, the new standard should reduce the cost of cleanup by more than 50 percent. The new TNB standard was included in August, 1997 in the EPA Integrated Risk Information System (IRIS) under CAS No. 99-35-4

There are sites where natural processes are degrading explosive compounds in the soil and groundwater. The continuing project, **Natural Attenuation of Explosives in Soil and Water Systems at DoD Sites (CU-1043)**, is evaluating the ability of natural degradation to effectively remediate explosive compounds. Working in the field, they are evaluating biomarkers and stable isotopes as monitoring tools for natural attenuation processes and developing a protocol for selection and implementation of natural attenuation of explosives. Both microbial DNA and lipids have been used successfully to relate microbial degradation

potential, microbial community structure, and changes in explosives concentrations spatially. If successful, natural attention represents a significant cost savings as compared to existing active remediation techniques.

Chlorinated Solvents

Chlorinated solvents have been used in massive quantities over the last four decades, and release of these liquids into the environment accounts for a significant portion of environmental contamination requiring cleanup. These contaminants have migrated through the subsurface and entered groundwater at more than 1,000 DoD sites. There is a comparable degree of contamination at Department of Energy (DOE) and private Superfund sites. The limiting factor to satisfactory remediation at more than 75 percent of the hazardous waste sites in the United States is restoration of groundwater quality. The technology chosen for remediation at more than 90 percent of the sites with contaminated groundwater is pump-and-treat which has been proven not to be cost effective. Estimates of the duration of pump-and-treat necessary to remediate contaminated sites fully range from decades to centuries, with the risk to exposure enduring until remediation is achieved. Although pump-and-treat can be effective in controlling the migration of contaminated groundwater, in-situ alternative treatment technologies are required to meet this need.

A component of the DoD's National Environmental Technology Test Sites (NETTS) Program, is the **Dover National Test Site (CU-866)**, at Dover AFB, Delaware. Depicted in Figure II-4, Dover is the only test site in the United States uniquely designed and permitted for experiments involving the controlled, contained release of dense nonaqueous phase liquids (DNAPLs). This is accomplished in specially designed, double-walled experimental cells within a naturally occurring water table aquifer which permits mass balance determinations leading to more precise quantitative performance evaluations. Activity at Dover during 1997 included the following:

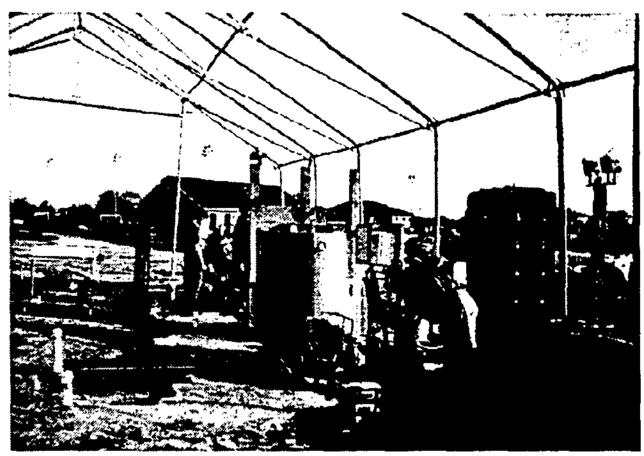


Figure II-4. The Dover Test Site Allows for DNAPL Controlled Release Experiments

- Jet Grouting. A public-private partnership called the DOE Barriers Group tested the emplacement of cost-effective impermeable barrier technologies. High-pressure jetting work began in 1997 to demonstrate feasibility of the technology.

- Chemical Flushing. SERDP is funding a series of tests to demonstrate chemical flushing techniques for removing DNAPL. Managed by the Air Force Research Laboratory (AFRL) and EPA, these tests use a unique double nested cell that consists of two conventional cells surrounded by a single outer containment barrier allowing for maintenance of an inward hydraulic gradient to contain the released contaminants.

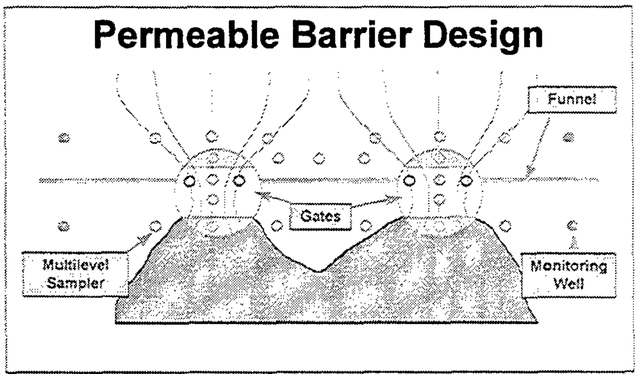


Figure II-5. The Process Diagram for Permeable Barrier Research

One of the most promising in-situ treatment technologies is reactive walls. This technology, commonly called "funnel and gate" consists of impermeable barriers installed in the ground to intercept the flow of contaminated groundwater and direct it toward a permeable section of the wall that contains materials which dechlorinate the contaminants. **Permeable Reactive Barriers for In-Situ Treatment of Chlorinated Solvents (CU-107)**, has installed an experimental reactive wall at the Dover Test Site. This project compares the performance of alternative reactive materials for funnel and gate systems through a field-scale proof-of-principle demonstration. The process diagram is depicted in Figure II-5.

Remediation goals, at times, have been established on the detection limits of instruments used to determine contamination rather than upon scientifically grounded rationale based on the risk to human health. The **Trichloroethylene (TCE) Risk Assessment (CU-115)** project has investigated the correlation between the remediation goals and the protection of human health. This research effort, depicted in Figure II-6, is presenting the U.S. EPA with a TCE risk assessment process which replaces non-scientific policy assumptions with science-based evaluation. Should the evidence demonstrate to the EPA a reduced risk, TCE limits may be raised. Such a change in the regulations will result in significant savings in cleanup costs and time. To support this effort, the physiologically based pharmacokinetic (PBPK) models that were developed for rodents and humans were transferred to the U.S. EPA this year for use in dose response assessment. In addition, three chapters were written supporting the state-of-the-science portion of the new trichloroethylene health assessment document that is under preparation by the U.S. EPA. A draft report of EPA's new trichloroethylene health assessment is expected to be available for public comment in CY 1998.

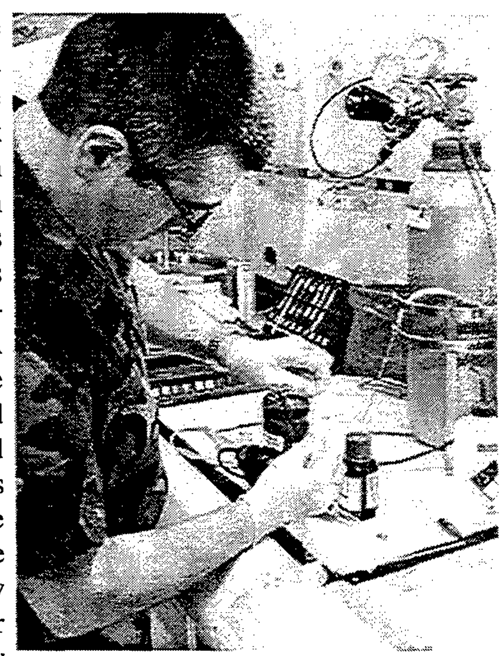


Figure II-6. Researchers at AFRL Pursue an Alternative TCE Risk Assessment

Bioremediation

The remediation of DoD sites using existing technologies is problematic from an economic, technical, and political point of view. The projected costs associated with site restoration using these current technologies are on the order of $30 billion dollars. These technologies are frequently invasive, requiring the movement of large volumes of soil and/or water and are also energy and materials intensive. In addition,

many of these technologies simply move the contaminant from the ground to the surface where it still must be treated. The **Federal Integrated Biotreatment Research Consortium: Flask to Field Initiative (CU-720)**, is a large, multifaceted project which develops field-ready biotechnologies in each one of the following thrust areas: 1) Explosives; 2) Polycyclic Aromatic Hydrocarbon (PAH); 3) Chlorinated Solvents; and, 4) Polychlorinated Biphenyls (PCB).

Since explosives contamination represents one of the most prevalent types of organic contamination within DoD, a variety of innovative and promising biotreatment techniques with potential high payoff have been and continue to be investigated for remediating soil and groundwater. The research into the remediation of TNT using plants was highly successful. As a result, a Patent Application has been filed entitled "Mechanism for Phytodegradiation of Munitions." In addition, a Method and Composition Patent was awarded in 1997. FY 1997 saw the operational startup of a fluidized bed reactor for the biodegradation of dinitrotoluenes(DNT) in contaminated groundwater at Volunteer Army Ammunition Plant. For enhanced biodegradation of TNT, a genetic modification technique has been employed to better understand how the environment controls the evolution of new genetic capabilities in microorganisms as well as the mechanisms of regulating the expression of these genes. Isolation of the 16S rRNA gene was successfully completed.

To achieve in-situ biotreatment of PAHs, the development, construction, assessment, and execution of preliminary mass transfer and biodegradation experiments using intermittently mixed slurry reactor has been completed. Under the PCB biodegradation thrust area, the catabolic capability of four target strains of bacteria was characterized based on the range of PCB cogener attack, their tolerance to high PCB concentrations, their growth rates and yield on biphenyl, and gram positive and gram negative cell walls. In addition, the scheme for transferring and expressing dehalogenase genes was successfully implemented.

These efforts in FY97 represent progress the Consortium has made along the path to achieve reduced remediation costs associated with development of "realistic" biotreatment processes for cleanup of contaminated DoD sites. Projected treatment costs are expected to fall at or below the $150 per cubic yard of soil treated (incineration costs are usually above $400/cy) or $1.00 per thousand gallons of groundwater treated (carbon costs are usually greater than $2.00/Kgal).

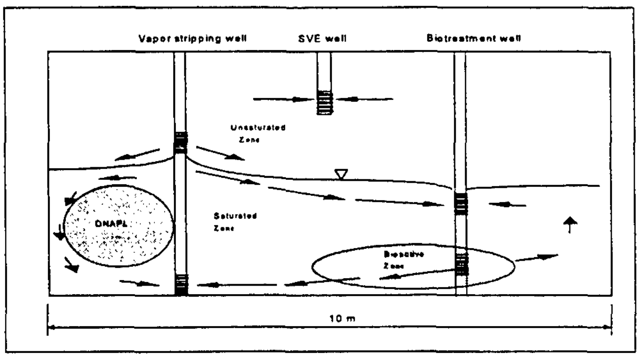


Figure II-7. Bioenhanced In-Well Vapor Stripping Field Experiment (GRFL Cell Cross Section)

The FY97 New Start, **Bioenhanced In-Well Vapor Stripping to Treat Trichloroethylene (TCE) (CU-1064)**, demonstrates that a combination of two in-situ treatment technologies, in-well vapor stripping and in-situ bioremediation, can be used to reduce and contain the high levels of TCE contamination found in the proximity of a non-aqueous phase liquid contaminated zone. The process diagram is depicted in Figure II-7. A numerical model which simulates recirculating groundwater flow; transport of dissolved TCE, toluene, and oxygen; cometabolism; and in-well volatilization of dissolved TCE has been completed. The constituents simulated have been

pure-phase and dissolved TCE, toluene, dissolved oxygen, and biomass. Preliminary site-specific design studies showed that the technology could be demonstrated in the confines of a Groundwater Remediation Field Laboratory field demonstration test cell at Dover Air Force Base.

Efforts also have continued at the **National Test Site Location at (Former) Wurtsmith AFB (CU-864)** to pursue bioremediation advances. Technologies with evident promise for complete and cost-effective remediation with minimal environmental disruption are favored for facility usage. These technologies involve on-site and in-situ processes which integrate biological and physicochemical methods. Recent efforts have provided evidence from more than 10 sites at the former Wurtsmith AFB in Oscada, MI, confirming the intrinsic bioremediation of fuel and chlorinated mixtures in both aquifer materials and groundwater. The disappearance of dissolved parent compounds, increases in alkalinity, and changes in electron acceptor/donor concentrations all support this conclusion.

Compliance Accomplishments

Alternatives to Incineration/Thermal Destruction of Shipboard Wastes

To maintain operational readiness, Navy ships must be able to access ports and bodies of water around the world without operational constraints related to environmental laws and regulations. Navy vessels generate a variety of wastes, including garbage, plastics, black water, grey water, oily waste, and sludges. In the near future, domestic and international laws will prohibit overboard waste discharge and storage/off-loading of these wastes. Within the U.S., the Clean Water Act restricts discharges to waters in U.S. ports. At the international level, the International Maritime Organization's Marine Pollution Convention (MARPOL) Annexes will restrict or prohibit operations in international waters unless vessels meet international environmental statutes. Thermal destruction (i.e., incineration) is considered to be the most viable solution beyond the year 2000 for all types of shipboard waste. However, commercial incinerators are too large for Navy vessels and, at present, may not meet emerging incineration emissions standards.

In response to this need, the **Compact Closed-Loop Waste Incineration (CP-34 & 887)** projects have developed and demonstrated incinerator technologies that allow design of high efficiency incinerators small enough to be suitable for Navy vessels. The new compact technology uses resonant acoustics in the primary combustion chamber to enhance the burning rate of solids and improve the burning characteristics of liquids. In addition, it uses active combustion control to establish and maintain acoustically stabilized vortices in the secondary chamber to improve the efficiency of the afterburning process (see Figure II-8).

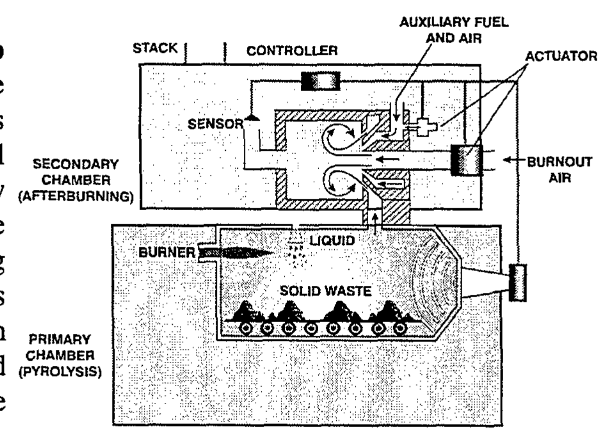


Figure II-8. Diagram of New Compact Incinerator Technology to be Used for the Destruction of Shipboard Wastes

Demonstrations conducted as part of this project have confirmed that resonant acoustics can significantly increase the throughput of solid waste. Additionally, use of the active-control process can enable a reduction in afterburner size by a factor of more than five while significantly increasing combustion efficiency. The combination of these technologies reduces emissions of unburned hydrocarbons, CO, and NOx. Sensors monitor the exhaust in real-time to optimize the waste destruction efficiency, exceeding 99.999 percent, for assured pollution-free waste destruction.

Innovative Tools For Open Burning/Open Detonation of Energetics

The downsizing of U.S. forces has led to a significant increase in the stockpile of unusable munitions and energetic materials. The current inventory is 500,000 tons and is growing at a rate that exceeds 50,000 tons per year. One relatively simple and cost-effective method to reduce this stockpile is open burning/open detonation (OB/OD). However, OB/OD activities can generate unacceptable air pollutants. Therefore, any facility that intends to use OB/OD must meet strict permit requirements under the Resource Conservation and Recovery Act (RCRA) and characterize the risks to human health and the environment from OB/OD air emissions. To date, few permits have been granted and those that have are issued on an "Interim Status" basis and are highly restrictive.

Two projects, **Characterization of Open Burning/Open Detonation (OB/OD) Emissions (CP-247)** and **Measuring and Modeling for OB/OD Permitting (CP-251)**, have developed new technologies to obtain the risk-related information required for OB/OD permit approval. This characterization project first developed a contained "Bang Box" in order to collect and analyze various energetic emissions. This was followed by development of an enhanced "Bang Box," the ODOBi (see Figure II-9), that accommodated testing entire munition rounds and reduced noise, thereby allowing for the further characterization of the emissions from a wide variety of munitions for use as source term in the modeling project.

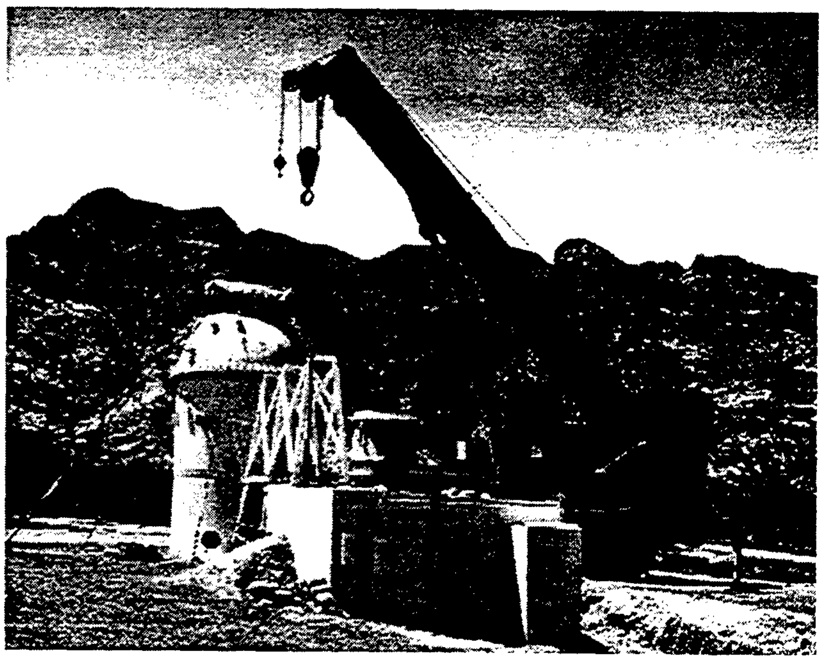


Figure II-9. ODOBi Can Characterize Emissions of up to 25 lbs of Explosives in Support of Risk Assessments for RCRA Subpart X Permits

In order to better characterize and predict through dispersion modeling the ground-level concentrations and deposition of materials released by OB/OD activities, observation platforms and atmospheric remote sensing instrumentation for characterizing meteorological data to 2,500 meters above OB/OD sites were

built. Real-time surface and upper air data, including wind and temperature profiles, humidity, solar radiation, and turbulence variables, are used with the dispersion models to predict site-specific impacts of OB/OD activities. Dispersion models developed under this project have been validated with field and laboratory observations to predict how pollutants generated by OB/OD will move in the environment.

Emissions data from the Bang Box has been accepted by the EPA Office of Solid Waste, all EPA Regions, and several states. Broad acceptance of these data significantly eases the permitting process. Other countries with large munition stockpiles also will benefit from this OB/OD technology.

Atmospheric Monitoring

The Air Force and Navy need additional air emissions data for rockets, jets, and ships in order to comply with the requirements of the 1990 Clean Air Act Amendments. Existing analytical equipment are inadequate to detect, monitor, and characterize airborne pollutants and lack required sensitivity, selectivity, portability, and robustness to perform field measurements. The **Advanced Mass Spectrometry For Atmospheric Monitoring (CP-192)** project developed and demonstrated an ultra-sensitive mass spectrometer using selective chemical ionization for detection and measurement of trace gas-phase neutral pollutant gas molecules in the stratosphere, troposphere, and ground level atmosphere.

An immediate benefit of the research will be to ensure compliance of jet or rocket engine emissions with mandated standards and to support DoD efforts to reduce pollution from jet and rocket operations. The end product of the research is a portable, highly sensitive and calibrated, yet effective and robust instrument with proven performance for determining trace neutral chemical composition in the atmosphere with greater than a trillion-to-one dynamic range and part-per-quadrillion sensitivity.

An extensive field campaign was conducted (as part of the NASA SUCCESS mission). A prototype instrument was employed aboard a WB-57F weather research aircraft to 61,000 feet in measuring ozone, HCl, Cl_2, and ClO in Titan IV rocket exhaust plumes. The system has proven itself capable of long periods of operation under field conditions with a minimum of field service. Measurements of HCl, Cl, Cl_2, ClO, and O_3 in the plumes will lead to understanding of the mechanism of ozone depletion by solid rocket exhaust and to an assessment of the degree of the ozone depletion attributable to launch operations.

In a second test, the NASA Subsonic Assessment program sought to understand the impact of jet engine exhaust on upper troposphere/lower stratosphere chemistry and energy balance and on the properties and mechanisms of cloud and contrail formation. As a part of this large effort, another advanced mass spectrometer was installed in a T-39 jet flown in close formation behind F-16 lead aircraft that burned fuels with varying sulfur content. Gas phase HNO_2, HNO_3, SO_2, and H_2SO_4 in jet exhaust plume were measured to assess the role of these species in heterogeneous or binary nucleation and subsequent contrail formation.

Air Emissions Reduction

The Clean Air Act sets tough standards for emissions of nitrogen oxide (NOx) in ozone non-attainment areas. These standards are forcing the Air Force and other military agencies to reduce their overall NOx emissions on their installations by as much as 40 percent. McClellan AFB, California, has shown that 35 percent of its annual NOx emissions come from hour-rated diesel engines, a majority of which are found on ground support equipment for pre- and post-flight operations. In an effort to help McClellan AFB and other DoD facilities reduce these emissions, the Air Force Research Laboratory (AFRL) with funding from SERDP developed a system, **Metal Perovskite Catalysts for NOx Reduction (CP-177)**, to capture both the NOx and particulate pollutants at generation sites and treat the NOx pollutants off-line.

The system is contained on a portable cart as shown in Figure II-10. A vermiculite prefilter removes particulates. A heat exchanger lowers the exhaust gas temperature, increasing the activated carbon NOx adsorption. The activated carbon will adsorb approximately 5-8 percent of its weight in NOx which gives the cart a 50 to 100 hour operating run before regeneration is required.

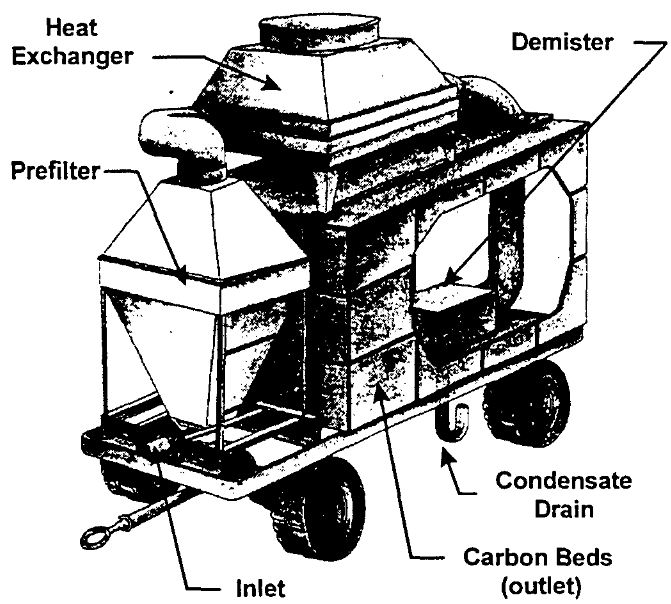


Figure II-10. Diagram of the NOx Filter Cart Which Uses a Heat Exchanger and Activated Carbon to Reduce Nitrogen Oxide Emissions

AFRL, Sorbent Technologies, and Applied Research Associates, Inc. received a 1997 R&D 100 Award from *R&D Magazine* for the NOx and particulate filter technology. Extensive tests were conducted capturing the exhaust from an A/M32A-86 diesel generator at McClellan AFB. The NOx Filter Cart was tested on other diesel- powered support equipment, from 60 kW mobile diesel generators to a 500 kW diesel backup power generator. NO and NO_2 removals ranged from 92-100 percent in tests of three hours and longer. At a projected cost of $12,000 per unit and annual operating costs of $15,000 the NOx Filter Cart could have a payback of slightly more than one year if used to avoid $25,000 noncompliance fines. The next-generation NOx Filter Cart will be designed for in-place regeneration of the activated carbon. AFRL is also investigating potential industrial uses of the concentrated NOx and VOC mixture.

Conservation Accomplishments

Ecosystem Management Initiative: SERDP Management Scale Ecosystem Research Workshop

DoD's ability to conduct mission essential training and testing is often linked to its understanding of the ecosystem and its ability to cost-effectively manage critical natural resources in concert with missions needs. Ecosystem Management of natural resources is a goal-driven approach/process to environmental management that recognizes social and economic viability within functioning ecosystems and is: at a scale compatible with natural processes; cognizant of nature's time frames; and realized through effective partnerships among private, local, state, tribal, and Federal interests. The overall goal of Ecosystem Management is to maintain and improve the sustainability and native biological diversity of terrestrial and aquatic, including marine, ecosystems while supporting human needs, including the DoD mission.

The DoD is required by the Deputy Under Secretary of Defense for Environmental Security to ensure that Ecosystem Management becomes the basis for future management of all DoD lands and waters [DUSD(ES) 8 August 1994 Memorandum to all Services]. In addition to this mandate, the DoD has a number of user requirements to properly maintain training and testing facilities, as well as to preserve and enhance the natural resources under its control. All of these user requirements are linked to the concept of Ecosystem Management.

The SERDP Scientific Advisory Board recognized that there are both gaps in knowledge and understanding of fundamental ecological processes, and SERDP is in a unique position to facilitate ecological research at the management scale by using ongoing government activities and facilities. The SERDP Council endorsed the Scientific Advisory Board recommendation to organize a workshop to help identify critical deficiencies in fundamental ecological science while simultaneously identifying and focusing on research opportunities that address the applied ecosystem management problems on defense installations.

The workshop was held in June, 1997. Participants included 15 leading ecological and environmental scientists, three representatives of DoD land and water resource managers, as well as 30 advisors and observers from relevant Federal agencies and non-governmental organizations.

A common theme to emerge from the discussions at the workshop was that there is a need for better indicators of ecosystem health; those attributes of an ecosystem that can be used as a yardstick by which to measure overall health of an ecosystem or to serve as an early warning of ecosystem change. Three key findings to emerge from the workshop are listed below.

1. Scientific understanding of ecosystems has the potential to provide methods to speed up and improve restoration.

2. The mix and distribution of plant and animal species present affects the kind and rates of restoration of biogeochemical cycles. The reestablishment of desired biogeochemical cycles in a disturbed area, therefore, depends on the availability of colonizing species.

3. Biological diversity, including the conservation of specific endangered species, is an important concern on DoD lands and waters. Disturbance regimes, unique or rare ecosystems, and jurisdictional control which are characteristics of DoD lands provide the potential to improve the scientific understanding of the ecosystem role of biological diversity.

Based on the results of the workshop, SERDP together with the U.S. Army Construction Engineering Laboratory developed an integrated research initiative known as the SERDP Ecosystems Management Project (SEMP). The first projects under this new initiative will be funded in FY 1999.

Resource Monitoring and Impact Analysis

Figure II-11. GPS Locator on Peregrine Falcon

Acquisition of good scientific information on free ranging organisms to fully elucidate their relationships with habitat and land use activities is critical to the development and implementation of effective natural resource management plans. Such plans will allow the DoD to maintain biodiversity, conserve natural resources, and comply with environmental laws and regulations.

The use of advanced, satellite-based tracking and monitoring technologies to acquire natural history information necessary for effective management and conservation of widely-ranging animals could save DoD roughly 10-30 percent over currently available best methods (i.e., conventional, ground-based radio telemetry). In partnership with the U.S. Army Edgewood Research, Development and Engineering Center (ERDEC) and the Johns Hopkins University Applied Physics Laboratory, the SERDP project **Advanced Biotelemetry for Resource Management (CS-759)** has developed satellite-based advanced information gathering technologies that provide a stand-off capability to gather natural history information on migratory or widely ranging target species, including threatened and endangered species such as the peregrine falcon. These technologies include (a) Global Positioning System (GPS) platform transmitter terminal (PTT), which provides location estimates to within about 100 meters, (b) new meteorological sensors, and (c) an acoustic sensor that will be small enough to be integrated into the PTT to perform a variety of functions. The enhancement in location accuracy of GPS receivers over previous technology (i.e., Doppler locations) represents a quantum leap forward in the application of radio-telemetry to wildlife science (See Figure II-11).

Prototypes of the developed GPS PTTs have been field-tested successfully, yielding greatly improved accuracy of satellite transmitter location fixes. PTTs were used successfully to track the movements of Golden Eagles and Feruginous Hawks in relation to the Idaho Army National Guard Orchard Training Area and the Snake River Birds of Prey National Conservation area. Also, a comparison between the GPS and Doppler location estimates was demonstrated successfully on sheep on a rural Maryland farm and wild ponies on Assateage National Wildlife Refuge, VA. This effort has been transitioned successfully into the DoD Legacy Resource Management Program.

Another high-priority concern to the military involves assessing the impact of proposed low-level flying aircraft operations on the environment. The public, U.S. Fish and Wildlife Service, and the National Park Service also have raised concerns that aircraft overflights may disturb nesting birds of prey or raptors. **The Effects of Aircraft Overflights on Birds of Prey (CS-89)** was funded to refine and validate an interim raptor dose-response model to predict these effects.

In close coordination with the University of Alaska-Fairbanks and Oregon State Cooperative Fish and Wildlife Research Units (U.S. Geological Survey, Biological Resources Division), and Alaska Biological Research, Inc., the Air Force collected extensive field data over three seasons. This data involved more than 2,900 overflights and included both behavioral observations by the field crews and remote noise event monitoring by the Animal Noise Monitors (ANMs) deployed in experimental, control, and "off-river" locations. Preliminary results indicate that the birds do not abandon their nests or show other dangerous overt signs of panic. A statistical review of the data is currently underway to define the short- and long-term effects of noise stress on the raptors.

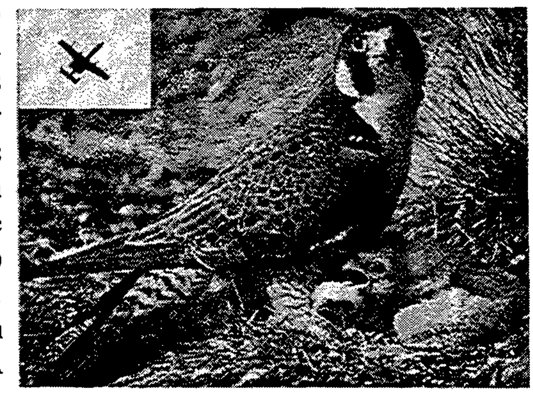


Figure II-12. Assess Impacts on Nesting Raptors

The validated interim raptor dose-response model, developed by the Air Force Research Laboratory, is being incorporated into the Air Force's Assessment System for Aircraft Noise (ASAN) used to provide support for the National Environmental Policy Act (NEPA) and other environmental impact documents. A scientific understanding of these issues allow our forces to effectively train while still protecting the environment.

Resource Management

DoD resource managers and military planners must determine how to balance multiple land uses, comply with resource regulations, and assess impacts to sustainability of the resource base from the military training and testing missions. To address this very complex issue, SERDP funded the **Strategic Natural Resource Management Methodology (CS-373)**. Through this effort, the DOE's Argonne National Laboratory and the U.S. Army Construction Engineering Research Laboratories developed a computer-based, dynamic landscape modeling system to help sustain natural resources and to support and facilitate military training activities by linking these objectives into a single decision support system. This prototype modular system, Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS), consists of ecological, erosion, and training sub-routines, along with advanced decision support techniques combined with a core vegetation dynamics model that utilizes geographic information systems (GIS), remote sensing, and field inventory data. In their planning process, the installation resource manager can

now (1) identify multiple land use objectives and incorporate trade-off analysis; (2) evaluate the cost and economics of viable land use management alternatives; and (3) incorporate "what-if" scenarios into his decision making (Figure II-13). IDLAMS supports land-use management responsiveness and military operations, enhances environmental compliance, and balances multiple land use objectives.

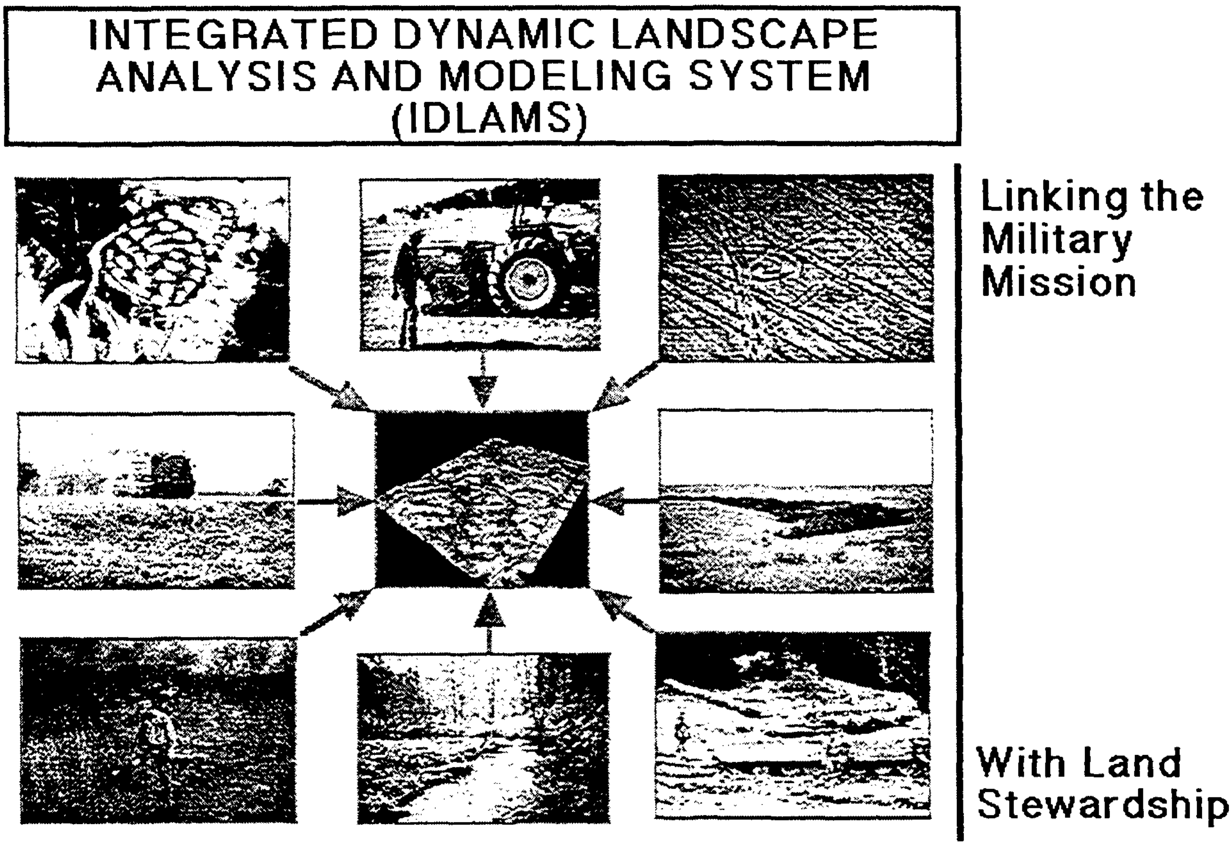


Figure II-13. IDLAMS - Linking the Military Mission with Land Stewardship.

Pollution Prevention Accomplishments

Non-Halon Fire Suppression Technology

In response to a DoD directive stemming from the *1987 Montreal Protocol on Substances that Deplete the Ozone Layer*, the Office of the Director of Defense Research and Engineering (ODDR&E) created the Halon Alternatives Research & Development (R&D) Steering Group (HASG) to develop and execute a DoD technology strategy to address the need for near-term alternatives to chloroflorocarbons (CFCs), Halons, and other ozone depleting substances (ODSs) in weapon systems. In June 1993, the HASG published a technology development plan (TDP) to identify and/or develop feasible ODS alternatives.

While near-term Halon 1301 fire suppression alternatives developed under the TDP may possibly be applied to new weapons system designs, they typically require weights and/or volumes that are 2-3 times that of Halon 1301 for equivalent effectiveness and pose potential problems to existing weapon systems because of form, fit, and function constraints, as well as cost of retrofit.

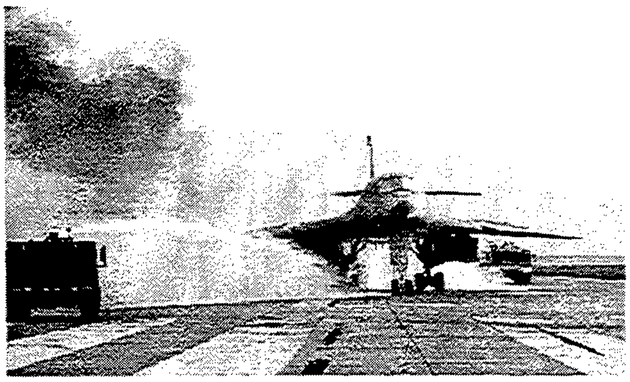


Figure II-14. Ozone-Friendly Fire Suppressants to Replace Halons

To address this, the HASG formulated the **Next Generation Fire Suppression Technology Program (NGP) (PP-1059)**, a logical extension of the TDP effort. The eight-year, $46M NGP was initiated in October 1996, with the goal to develop and demonstrate by the year 2004, Halon alternatives that are easily retrofitable into currently fielded weapons systems. In 1997, 10 SERDP-funded research projects were initiated under this government/academia/industry partnership of which nine research projects will address Mechanisms of Ultra-High Efficiency Chemical Suppressants, Suppression Dynamics of Fine Droplets and Particles, Stabilization of Flames, Suppression System Effectiveness Screening, and Advanced Propellants/Additive Development for Gas Generators. An additional 25 new projects will be funded by the Military Departments and SERDP beginning in FY 1998.

Additionally, the **Advanced Fire Fighting Streaming Agent (PP-158)** project developed a drop-in replacement for Halon 1211 to fight flight line fires (Figure II-14). AFRL researchers were successful in developing unsaturated brominated compounds and blends of tropodegradable agents, such as octafluoro-butene and 1-bromopropane, as the Halon 1211 replacement favored to fulfill all streaming agent requirements. Chemical structure modeling developed as part of this effort was transitioned to the NGP project for use in developing and evaluating possible alternatives to Halon 1301.

"Green" Energetic Materials

Currently the DoD Single Manager for Conventional Ammunition manages nearly 20 different families of munitions grouped into solid rocket propellants, gun propellants, explosives, and pyrotechnics. General environmental problems associated with munitions include the need to eliminate toxic ingredients and volatile organic compounds (VOC) and reduce wastes generated during their production and use.

SERDP has played a significant role leveraging resources from the Army and Navy to address high-priority areas for all of the four major munitions groups discussed above. SERDP developed next generation energetics such as thermoplastic elastomers (TPEs), tri-nitro azetidine (TNAZ), and ammonium dinitramide (ADN).

As the SERDP flagship energetics project, **DoD/DOE Clean Agile Manufacturing of Energetics (CAME) (PP-63)** has demonstrated the use of recyclable ingredients and cleaner manufacturing processes to reduce pollution of the energetics components of the munitions. The CAME project demonstrated a manufacturing procedure for TPEs using water and liquid carbon dioxide rather than ODSs. Because current explosive materials cannot be safely separated from the polymers that bind them together, their disposal creates significant environmental and safety problems. When physically linked TPEs replace chemically (irreversibly) linked polymers, it will be possible to recover, reuse, and recycle many of the ingredients in military explosives and propellants. In addition, TPE manufacturing procedures will not require the use ozone depleting substances.

Additionally, as part of the CAME project, SERDP is participating in a joint program with Sweden to determine the environmental advantages, if any, of using ammonium dinitramide (ADN) as a potential replacement for the chlorinated explosive and propellant ingredient, ammonium perchlorate (AP). The joint program is conducted under the auspices of a Memorandum of Understanding (MoU) between the DoD and the Armed Forces of the Kingdom of Sweden. As part of the CAME spin-off project, **Solventless Manufacture of Artillery Propellant Using TPE Binder (PP-867)**, the Principal Investigator is evaluating the use of TPE binders developed as part of the CAME project for use in 155mm Howitzer gun propellants.

Another SERDP funded project, **Laser Ignition to Replace Chemical Ordnance Igniters for Propulsion (PP-680)**, successfully developed a laser ignition system to replace lead styphnate compounds used in primer for the PM-Crusader Advanced Solid Propellant Armament (ASPA) system Howitzer. The replacement of chemical primers in the Crusader Howitzer eliminates the use of 50 tons of hazardous material per year. This technology is being expanded to include Army small caliber weapons, and a cooperative research and development agreement (CRADA) with Remington Arms was drafted to explore the transfer of SERDP supported technology to the small arms commercial marketplace. Overall, more than 14 Small Business Innovation Research (SBIR) programs and 5 CRADAs have been established. The ultimate objective of this project is to develop a universal laser ignition system for armaments. Figure II-15 shows the Laser Ignition System developed as part of PP-680 project to replace lead-containing primers and igniters for 155mm the Paladin cannon.

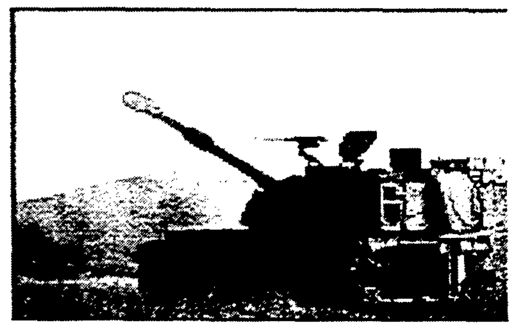


Figure II-15. Paladin Installed with Laser Ignition System.

Modeling and Databases

DoD and DOE facilities and supporting industries need fast, easy access to integrated network information on available substitutes to meet the impending phase outs of ozone-depleting substances, reduction of toxic materials under the Clean Air Act and Executive Order 12856. **Integrated Expert Solvent Substitution Data Base (Enviroene) (PP-331)**, created a Federal Pollution Prevention network by integrating technical information from other Federal agencies. Enviroene information may be used to implement

pollution prevention and solvent substitution programs, ensure compliance with environmental laws and regulations, solve enforcement cases, and develop research projects.

The Enviroene network has been developed as a distributed system to relay pertinent technical pollution prevention information to all Federal agencies, and specifically, to house an expert architecture known as the Solvent Umbrella. The Solvent Umbrella utilizes state-of-the-art electronic navigation, translation, and search tools in the Internet environment. The Umbrella allows users to access solvent alternative information through a single, easy-to-use command structure that will seamlessly access and retrieve information from its component databases.

A sample of the databases incorporated in the Umbrella include EPA's Solvent Alternatives Guide (SAGE); Idaho National Engineering Laboratory's (INEL) Hazardous Solvent Substitution Data System (HSSDS); INEL's Solvent Handbook Data System (SHDS); the Naval Facilities Engineering Service Center's (NFESC) Pollution Prevention Library ODS and Solvent Alternatives databases; and EPA's Enviroene integrated vendor database. The Umbrella allows the user to tap into applicable Mil-Specs, Technical Orders (TOs), National Stock Numbers, and Material Safety Data Sheets, where appropriate. The Enviroene network and its component Solvent Umbrella is being deployed through a permanent site on the World Wide Web hosted by EPA at Research Triangle Park, NC (**http://www.earth2.epa.gov**).

Through another SERDP-funded effort, **Life Cycle Engineering and Design Program (PP-304)**, Life Cycle Assessment (LCA) principles were applied to selected DoD operations in order to identify and test potential technical solutions to reduce reliance on toxic chemicals and solvents industrial and DoD operations. LCAs and technology evaluations have been completed under this program with the Air Force, Army, and Navy identifying improvements and demonstrating efficiencies. EPA's National Risk Management Research Laboratory has tested solvent formulations of propylene carbonate, n-methyl-pyrolidone (NMP), and non-NMP formulations as possible alternatives for MEK and methylene chloride in aircraft radome and fuselage depainting. Technology demonstrations with the Army showed the potential for significant real reductions in the quantity of CARC paint needed to coat military vehicles and demonstrated the fact that painting operations in the field can vary significantly among installations. A life cycle inventory conducted with the Navy and DOE has identified the environmental effects of selected energetic materials. Based on lessons learned in these and other LCAs of industrial operations being funded by EPA, a design guide was generated for implementing life cycle principles on environment, performance, and cost as an aid to decision-making.

Alternative Coatings

Starting in 1994, several stringent environmental regulations such as National Emissions Standards for Hazardous Air Pollutants (NESHAP), Occupational Safety and Health Administration (OSHA) regulations, and Executive Order 12856, requiring a 50 percent reduction in toxic waste transferred off-site from Federal maintenance activities, dramatically impacted DoD core depot and field level operations. Within the Air Force alone, painting and depainting activities account for 75 percent of the pollutants generated. The two most important performance factors for new coatings and coatings removal technologies are survivability and corrosion resistance/protection which must be maintained while reducing the volatile organic compounds (VOC) and hazardous air pollutant (HAP) content.

Primers designed for use on aircraft contain carcinogenic chromates as corrosion inhibitors. The Clean Air Act of 1990 places severe limits on the type and quantity of chemical emissions and will only allow the use of materials containing high levels of HAPs or VOCs when expensive high-efficiency emission-control equipment is in place. OSHA has proposed a permissible exposure limit (PEL) of 0.5 $\mu g/m^3$ for chromium. Both regulations are planned to take effect in September of 1998. Removal of chromates from aircraft priming will result in the avoidance of the capital cost of emission-control equipment (up to $5M per hangar) and the imposed fines (as high as $25,000 per day per facility) as well as providing reductions in hazardous material disposal costs.

DoD has unique coatings requirements to meet its military mission. In particular, Chemical Agent Resistant Coatings (CARC) has no commercial equivalent. The primary deficiency in current CARC is the excessive levels of VOC in the polyurethane topcoat. At current production levels, 10 million pounds of VOCs are emitted per year into the atmosphere from CARC painting operations. The existing CARC topcoat has a VOC content of 3.5 lb/gal, whereas local requirements are as low as 1.8 lb/gal. The **Low VOC Chemical Agent Resistant Coatings (CARC) (PP-1056)** project focuses on the high performance, water reducible polyurethane binder systems which have been demonstrated to have desired chemical agent resistance and meet the tri-service performance requirements. Significant accomplishments to date include establishing a low VOC formulation for the basic Army green camouflage color. The formulation meets the VOC requirement of 1.8 lb/gal (max.) as sprayed and is HAP free. The formulation meets or exceeds all performance requirements of the currently fielded CARC topcoat. Significant improvements in flexibility, particularly at low temperature, have been achieved as well as marked improvements in mar resistance.

Figure II-16. Non-Chromated Primer Applied to T-2 Aircraft.

As part of another effort, **Organic Protective Coatings and Application Technology (PP-65)**, non-toxic, non-chromated corrosion inhibitor systems have been developed and a joint industry-Navy effort has resulted in a non-chromated primer which is suitable for field testing. Spraylat's EWDY048 non-chromated waterborne primer qualified to MIL-P-85582, Class N, a new classification that allows for non-chromated materials. The Naval Aviation System Command validation continues on a T-2 aircraft that was painted (Figure II-16) at Naval Aviation Depot, Jacksonville, FL, in March 1996, and an F-18 access panel painted at Naval Air Warfare Center, Patuxent River in September 1996. There have been no reported problems to date. Additionally, the Spraylat material is also one of two candidates that has been down-selected for application demonstrations on F/A-18 aircraft at NADEP North Island, CA, through the Joint Group for Acquisition Pollution Prevention (JG-APP) after intensive screening. Other aircraft targeted for priming with the new materials are the T-45, AV-8, and F-15 (wings only).

Through the **Aircraft Maintenance Chromium Replacement (PP-66)** project, non-chromated alternative technologies were developed to replace all uses of chromic acid anodizing (CAA), resulting in a reduction

of three tons/year in chromated waste per maintenance facility. For pre-painting applications, sulfuric/boric acid anodizing (SBAA) and thin film sulfuric acid anodizing (TFSAA) were the best alternatives for CAA, while phosphoric acid anodizing (PAA) gave the best properties for pre-bonding. Use of the replacement technologies results in savings of approximately $1M capital equipment costs and $375-450K annual operating and disposal costs per maintenance facility per year, while maintaining corrosion resistance, paint adhesion, and adhesive bond strength.

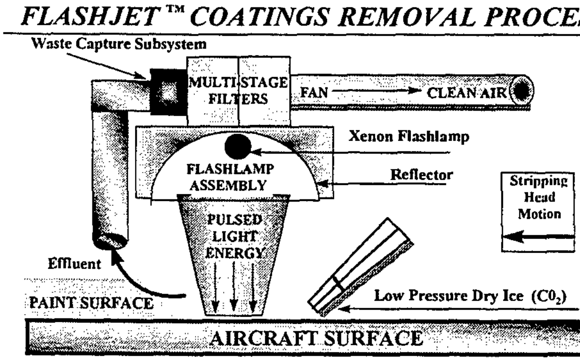
The SBAA process was transitioned in 1997 to a full-scale demonstration at NADEP North Island. NAVAIR approved the use of SBAA, and the MIL-A-8625 process specification was revised to include both alternatives. SBAA has been transitioned to full-scale use at North Island and Cherry Point and is scheduled for transition at Jacksonville. TFSAA is under consideration for use in the H1 Helicopter Upgrade program. A PAA tank was installed at NADEP Cherry Point for pre-bonding applications.

Coatings Removal Technologies

The chemical paint strippers historically used by DoD and the aerospace industry have been formulated with methylene chloride and phenol activators which are toxic and hazardous materials. Paint stripping is time consuming and produces hazardous air pollutants and large quantities of hazardous waste, requiring expensive treatment and disposal procedures. In 1996, chemical stripping operations at a single DoD aviation depot required treatment of 1.7 million gallons of contaminated water. The CY 1997 treatment cost was $1.50 per gallon, requiring a recurring expenditure of more than $2.5 million per year.

To address this significant requirement, SERDP funded **Aircraft Depainting Technology (PP-81)** to develop, demonstrate, and validate a system for application of Xenon Flashlamp/CO_2 (Flashjet™) paint stripping on medium to large size aircraft. The effort leveraged support from the Chief of Naval Operations (N-45G) Aviation Pollution Prevention Program. Also under SERDP, Flashjet™ was tested extensively on aircraft thin, structural aluminum alloys and graphite epoxy composite lay-ups. These studies showed that the process can be used to remove paint systems selectively to the primer or substrate without damage to mechanical properties or adhesive bond strengths. On July 28, 1997, the Naval Air Systems Command released a process approval letter and specification for the use of Flashjet™ on all Navy aircraft metallic surfaces. Navy composites approval is expected prior to 1999.

FLASHJET™ COATINGS REMOVAL PROCESS



Synergism of Pulsed Light and Dry Ice

Figure II-17. Conceptual Design of FlashJet™ Coatings Removal Process

Because the process uses only dry ice and high intensity light for paint removal, the use of Flashjet™ will reduce an aviation depot's hazardous waste stream more than any other presently available paint stripping process. One particular Naval aviation depot's depainting building generated nearly 1.3 million pounds of hazardous waste in 1996, the vast majority attributed to chemical stripping. Installation of air emissions

and control equipment for methylene chloride and other hazardous air pollutants would incur an additional expense of approximately \$5.5 million. Utilization of the Flashjet™ process in the Navy's paint stripping strategy will reduce this waste stream to less than 400,000 pounds, resulting in a cost savings of approximately \$1.18 million per year at the depot. Figure II-17 shows the conceptual design of the Flashjet ™ coatings removal process being installed at NAS Kingsville.

III. PROGRAM DESCRIPTION

General

This section provides an overview of each of the Thrust Area Programs for FY 1997 and FY 1998 and planned FY 1999 initiatives for research within these Thrust Areas. The topics include the goals of each Thrust Area, the environmental and operational drivers directing needed technologies, and the major areas of R&D within each Thrust Area. Cross-reference is also provided to each project with respect to subtopic categorization and its completion status.

The SERDP Program contains four Thrust Areas: Cleanup, Compliance, Conservation, and Pollution Prevention. Each year the Program Office, with the assistance of the Technology Thrust Area Working Groups (TTAWGs) and Executive Working Group (EWG), determines the funding balance between these four Thrust Areas. Figure III-1 describes the distribution of funds to specific Thrust Areas for FY 1997 and FY 1998.

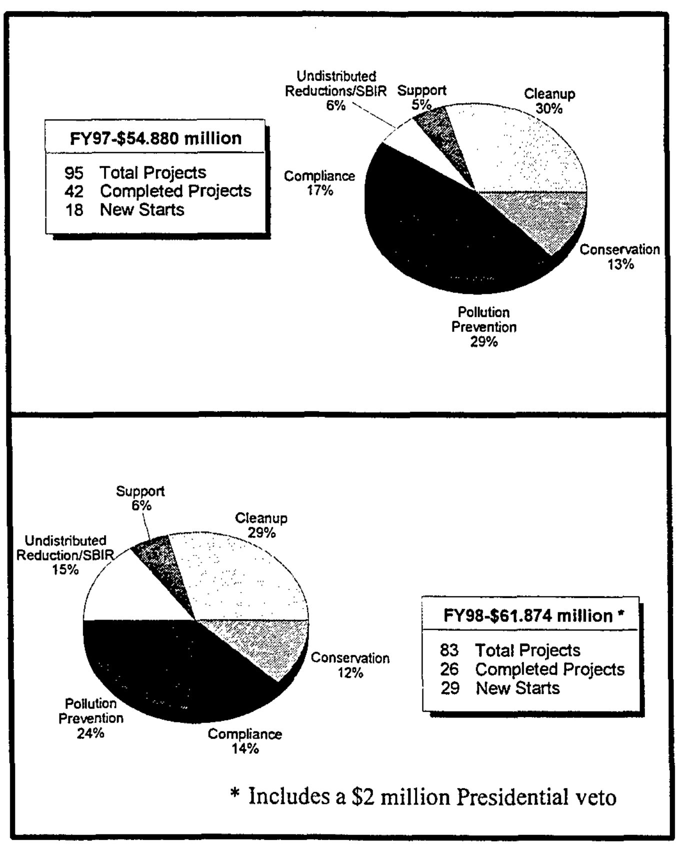


Figure III-1. SERDP Funding, FY 1997-FY 1998

Program Development

The SERDP FY 1997 Program was prepared in accordance with the established Congressional direction and further guided by policies provided by the SERDP Council. Participating SERDP organizations and their laboratories were asked to solicit proposals that responded to the high priority defense environmental needs as stated by the Deputy Under Secretary of Defense for Environmental Security. Each organization conducted its own internal down-select procedure and forwarded its best proposals to SERDP for consideration. SERDP's multi-agency TTAWGs were tasked with reviewing these submissions for technical merit and relevance as well as overall cost.

In response to previous Congressional language, the SERDP FY 1997 Program focused on defense environmental requirements and hence, did not solicit proposals for Global Environmental Change nor Energy Conservation/Renewable Resources. All proposals selected by the TTAWGs were brought forward for review by the SERDP Scientific Advisory Board prior to Council approval.

The FY 1998 SERDP Program was developed during FY 1997 in order to expedite timely project funding. The Executive Director, at the direction of the Council, embarked on an open solicitation for FY 1998 that encouraged direct submission of proposals by the non-Federal sector, including industry, non-profit entities, and academia. The solicitation appeared in the Commerce Business Daily and resulted in submission of over 350 preproposals, of which 85 were requested to submit full proposals. Each of the submitters responded to one of 12 Statements of Need, as published in the FY 1996 version of this report. Fourteen non-Federal sector proposals were selected for FY 1998 funding by the Council, and their summaries may be found in the list of FY 1998 New Start Projects within each Thrust Area Description section and in Appendices A through D.

CLEANUP

Introduction

DoD and DOE must protect human health and the environment, reduce remediation costs, and provide timely cleanup. Cleanup goals for the DoD are to:

- Attend to imminent threats to public health and safety;
- Remediate all defense sites having a significant public health risk as quickly as feasible within the constraints of available resources; and
- Expedite transfer of Base Realignment and Closure (BRAC) sites and Formerly Used Defense Sites (FUDS) to future owners.

DoD and DOE have a legal obligation to meet the Federal, state, and local environmental protection and public health regulations. They own and operate thousands of installations, ranging from training bases to industrial production plants. Many of these installations have been operating for half a century or longer. During most of this time the agencies, like much of American industry, operated their facilities without full respect for the environment nor an understanding of potential impacts.

Using today's technology, the cost to remediate DoD sites alone is estimated at $35 billion, and total cost of cleanup at current and former defense sites (including DOE sites) is projected to exceed $200 billion. Experience with past remediation technology development has demonstrated a significant return on investment. Defense environmental managers require cost-effective and timely remediation capabilities that focus on assessment, characterization, and treatment. Each Service has submitted its User Requirements for Cleanup, which are prioritized in the DoD Environmental Technology Requirements Strategy. These requirements can be grouped into environmental concerns. Within the Cleanup Technology Thrust Area, the primary environmental concerns are the need to:

- Implement timely, effective, and affordable methods for site characterization;
- Ensure the use of effective, affordable remediation technology; and
- Comply with various Federal, state, and local regulations for site remediation.

These concerns are addressed by the Cleanup subthrusts and research areas as depicted in Figure III-2.

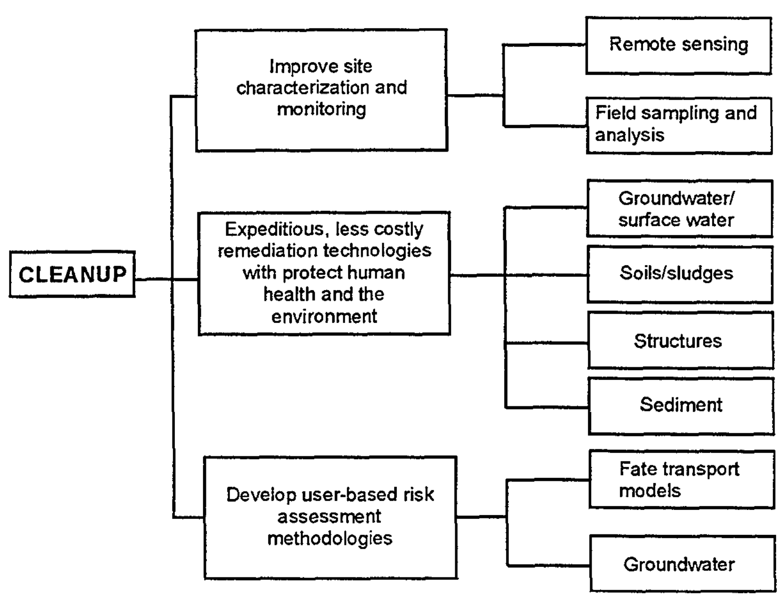


Figure III-2. Cleanup Taxonomy

Figure III-3 shows the FY 1997 and FY 1998 funding by subthrust area. For FY 1997, the Cleanup Technology Thrust Area received approximately 30 percent of the SERDP budget. While many defense cleanup situations will require that technologies be identified in the near-term, additional research in this area can still provide potentially the highest return on investment.

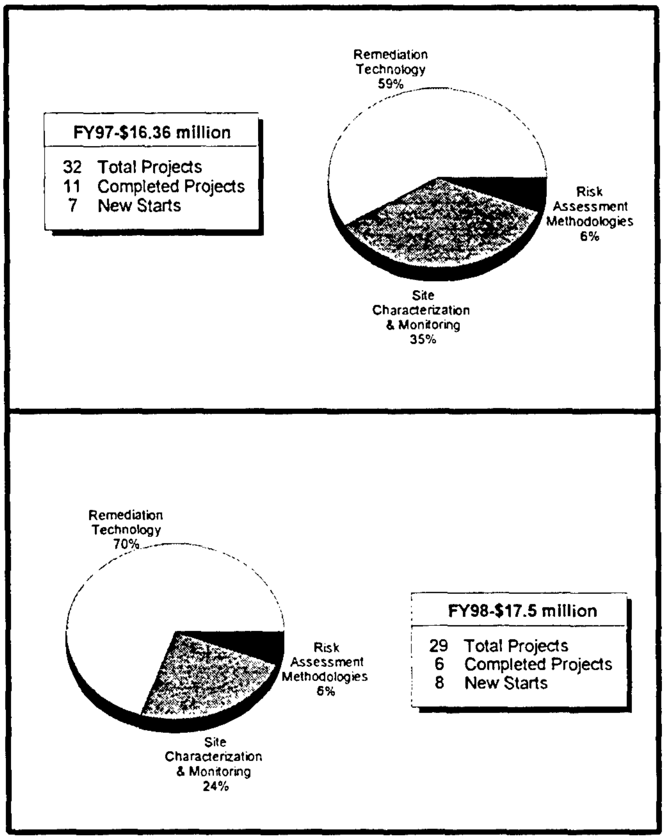


Figure III-3. SERDP Cleanup Funding, FY 1997-FY 1998

Principal Driving Requirements

The first subthrust area in Cleanup seeks to develop improved and less costly investigation and characterization technology for locating and characterizing wastes. Within this subthrust, the location, identification, and remediation of unexploded ordnance (UXO) has been identified by the Services as the highest priority user need. It poses an enormous challenge to the effective cleanup of many DoD sites, primarily on land but also under water. Current estimates indicate that up to 11 million acres of land in the U.S. are suspected to contain UXO as a result of military training and weapons testing activities--6 million acres of UXO contaminated Army and Navy land, approximately 5 million acres on Department of Interior land, and at least 50 sites at sea. These lands represent a full range of terrains, vegetative cover, soil types, and geophysical characteristics. The present cost, driven largely by the need to exercise

extreme safety precautions, ranges from $1,500 per acre for surface UXO to at least $5,000 per acre for sub-surface ordnance.

Identifying and characterizing sites contaminated with chlorinated solvents is another significant issue to the DoD. Chlorinated solvents represent a class of contaminants that is detected at more DoD sites than any other contaminant group. Chlorinated solvents have been used in massive quantities over the last four decades. Release of these liquids to the environment accounts for a significant portion of contaminated sites requiring cleanup. These contaminants have migrated through the subsurface and entered groundwater at over 50 percent of the contaminated DoD sites. There is a comparable degree of contamination at DOE and private Superfund sites. Estimated annual costs exceed $500 thousand for containing and monitoring a single dense non-aqueous phase liquid (DNAPL) plume. Novel technologies to detect and characterize these plumes will go a long way to assist in reducing these costs.

Cleanup's second subthrust focuses on a need to develop expeditious, less costly remediation technologies. Remediation of subsurface contamination of both soils and groundwater remains a high priority at DoD facilities. Because groundwater is mobile which could spread the contamination off base and is a much larger route of exposure than is subsurface soil, this subthrust is directed primarily at developing innovative technologies to better address groundwater remediation. Current groundwater treatment strategies typically employ pump-and-treat technologies which are expensive to operate and very slow to achieve lasting cleanup. Major limitations to the use of conventional pump-and-treat technology relate to difficulties in extracting contaminants from source areas where non-aqueous phase liquids (NAPLs) exist. Furthermore, presently employed technologies applied in pump-and-treat such as air stripping or activated carbon treatment do not result in final destruction of contaminants.

The challenges facing those involved with the nearly 17,000 sites on DoD installations potentially requiring environmental clean-up include: (1) distinguishing those sites that pose significant environmental risks from those that pose little risk; (2) prioritizing contaminated sites by the degree of risk posed; (3) quantifying the risks at each site; and (4) developing appropriate remedial actions and clean-up goals. Development of improved techniques for risk assessment, which provides a logical framework for making such decisions, is a DoD priority and the focus of this third Cleanup subthrust. The effectiveness of existing methods will be expanded by research directed at problems particularly evident at DoD installations.

Leveraging with other defense science and technology programs and industry, the Cleanup Technology Thrust Area focuses on the following research and development (R&D) objectives:

- Develop reliable and cost effective means to identify, assess, and clean lands and underwater areas (inland, estuarian and marine) contaminated with unexploded ordnance;
- Develop investigation methods and technologies that are capable of locating and characterizing wastes in a timely, cost effective, and quality manner;
- Develop innovative, compliant technologies that reduce remediation costs for sites containing explosives, propellants, fuels, solvents, heavy metals, organic contaminants, and other inorganic contaminants;

- Facilitate transfer of cleanup technologies to field use. This includes, but is not limited to encouraging the use of the National Environmental Technology Test Sites;

- Develop cost-effective, methods and tools to determine fate, transport, and effects of significant defense-related contaminants; and

- Develop risk-based modeling and simulation methods for hazard assessment and establishing cleanup priorities and scientifically defensible levels.

Cleanup Program

The following list reflects FY 1997 completed projects and projects continuing into FY 1998. Also included are titles of projects commencing in FY 1998. Complete descriptions of all of the projects for FY 1997 and FY 1998 may be found at the listed page numbers in Appendix A - Cleanup Project Summaries.

Subthrust 1 - *Improve Site Characterization and Monitoring*

Page

FY 1997 Completed Projects

Rapid Detection of Explosives and Other Pollutants A-3
In-Situ Bioremediation of Fuel and Efficacy Monitoring A-5
In-Situ "INSIDE-OUT" NMR Sensor for Contaminant ID A-6

FY 1998 Continuing Projects

Mobile Underwater Debris Survey System (MUDSS) A-7
Accelerated Tri-Services SCAPS Sensor Development A-25
Application of Neural Networks Coupled with Genetic Algorithms to Optimize Soil Cleanup Operations in Cold Climates A-39
Multisensor Data Fusion for Detection of Unexploded Ordnance A-41
Low-Frequency Ultra-Wideband Boom Synthetic Aperture Radar for Remote Detection of Unexploded Ordnance A-47
Unexploded Ordnance Detection by Enhanced Harmonic Radar A-49

FY 1998 New Start Projects

Negative Ion Sensors for Real-Time Downhole DNAPLs Detection A-59
Integrated Geophysical Multi-Sensor Detection of DNAPL Source Zone Identification . . A-61
Innovative Seismic System for Buried Unexploded Ordnance Detection and Classification A-63
Model-Based Data Fusion and Discrimination of UXO in Magnetometry and EM Surveys A-65
Environmental Impacts to the Chemical Signature Emanating from Buried UXO A-69

Subthrust 2 - *Develop Expeditious, Less Costly Remediation Technology*

FY 1997 Completed Projects

Joint U.S./Germany In-Situ Bioremediation Demonstration A-9
Bioremediation of Hydrazine A-14
Enhancing Bioremediation Processes in Cold Regions A-19
Bioremediation of Energetic Materials A-36
Selective Removal of Heavy Metals from Aqueous Wastes by Electrosorption on Functionalized Carbon Aerogels A-57

FY 1998 Continuing Projects

Permeable Reactive Barriers for In-Situ Treatment of Chlorinated Solvents A-10
Aquifer Restoration by Enhanced Source Removal A-15
Explosives Conjugation Products in Remediation Matrices A-20
Federal Integrated Biotreatment Research Consortium: Flask to Field Initiative A-22
National Environmental Technology Test Sites (NETTS) Program
NETTS Program - Consortium for Site Characterization Technology A-17
NETTS Program - McClellan AFB, CA A-28
NETTS Program - Naval Construction Battalion Center, Port Hueneme, CA . . . A-30
NETTS Program - Former Wurtsmith AFB, MI A-32
NETTS Program - Dover AFB, DE A-34
Natural Attenuation of Explosives in Soil and Water Systems at DoD Sites A-37
Development of Simulators for In-Situ Remediation Evaluation, Design, and Operation A-43
Bioenhanced In-Well Vapor Stripping to Treat Trichloroethylene A-45
Value-Added Site Monitoring & Infrastructure Maintenance for In-Situ Bioremediation A-53

FY 1998 New Start Projects

In-Situ Clay Formation: A New Technology for Stable Containment Barriers A-67
Assessment and Prediction of Biostabilization of Polycyclic Aromatic Hydrocarbons (PAHs) in Sediments A-71

Subthrust 3 - *Develop Risk Assessment Methodologies*

FY 1997 Completed Projects

Trichloroethylene Risk Assessment A-12
Environmental Risk Assessment Program (ERAP) A-27

FY 1998 Continuing Projects

Using Mode of Action to Assess Health Risks from Mixtures of Chemical/Physical Agents A-51

FY 1998 New Start Projects
Genosensor-Based Ecotoxicity Response Assessment A-55

FY 1999 Cleanup Initiatives

UXO detection continues to be the number one priority in the Cleanup Thrust area. To this end, a FY 1999 Statement-of-Need has been issued, **Novel Systems for the Detection and Identification of Buried Unexploded Ordnance (UXO)**. It focuses on the need to continue the process of identifying and developing innovative sensor systems and to integrate sensing technologies with high- performance sensor fusion and signal-processing algorithms for enhanced detection, location, and discrimination of buried UXOs under a wide range of environmental conditions.

The second proposed initiative within this thrust area is **Nonintrusive Methods for Dense, Non-Aqueous Phase Liquid (DNAPL) Source Zone Identification**. In the DNAPL Source Zone Identification area, a FY 1999 Statement-of-Need has been issued which seeks innovative technologies to detect, locate, quantify, and determine the horizontal and vertical extent of DNAPLs in the subsurface environment. Emphasis is on nonintrusive technologies for identification of DNAPL source zones. It focuses on innovative solutions and approaches that would ideally provide the desired information in real-time and in an easily interpretable format rather than enhancements or modifications of existing technologies.

A third FY 1999 proposed area of new research is **In-Situ Passive Treatment Technologies for Organics-and/or Metals-Contaminated Groundwater**. The primary emphasis of this need is to research and develop passive treatment technologies. Gaining acceptance as a cost-effective remedial action alternative for a variety of site conditions, passive treatment concepts are generally bounded by the limited variety of available materials. There continues to be a number of issues related to passive treatment technologies, such as biological fouling, capacity, efficiency, life cycle costs, etc. Considering these issues, research and development activities will be conducted at the bench, and in laboratory and small field scale tests to develop passive treatment systems for organics and/or metals contaminated groundwater.

The last FY 1999 proposed new initiative is entitled **Predictive Biological Assessment Using Tools and Techniques for Ecological Risk**. This initiative has been issued to develop remediation tools and response analysis techniques that would enhance/facilitate the development of technically defensible and cost-effective environmental risk assessment methodologies used to measure or quantify ecological impacts of hazardous waste cleanup. The main objective of this need is to develop risk-based assessment methods, tools, and technologies to help establish "how clean is clean or should be clean" that would result in a significant reduction in DoD's cleanup and disposal costs.

Detailed descriptions of the FY 1999 Cleanup Statements of Need may be found in Appendix E.

COMPLIANCE

Introduction

The Departments' Compliance goals are twofold:

- To ensure that all applicable environmental rules and regulations are met; and
- To eliminate or reduce the chances for Notices of Violation (NOVs).

Within the United States, DoD must comply with federal laws such as the Clean Water Act (CWA), the Clean Air Act (CAA), and the Resource Conservation and Recovery Act (RCRA), as well as state and local regulations. These laws result in requirements for the treatment and disposal of wastes generated during DoD operations and by vehicles, aircrafts, and vessels, and with respect to the open burning and open detonation (OB/OD) of waste energetics. Requirements based on the 1990 CAA amendments related to atmospheric emissions of hazardous air pollutants (HAPs), volatile organic compounds (VOCs), nitrogen oxides (NOx), and particulate matter (PM) are also emerging.

At the international level, the International Maritime Organization's Marine Pollution Convention (MARPOL) Annexes (to which the United States subscribes) restrict or prohibit DoD operations in international waters and MARPOL Special Areas unless vessels meet international environmental statutes. In addition, countries that host DoD facilities are implementing and enforcing compliance with regulations and standards that restrict or prohibit DoD operations in foreign ports and bases.

Virtually all DoD activities and assets are subject to compliance with a wide range of environmental statutes and regulations that have impacts ranging from control of hazardous materials and effluents to treatment methodologies. Affected DoD activities and assets include: training and operational installations; ordnance and weapons manufacturing; repair and rebuilding installations; and ship and aircraft operations. DoD is projected to spend between $2–3 billion annually for environmental compliance. New technologies must be developed to reduce this cost and enable the DoD to fully comply with increasingly stringent requirements so that it may fulfill its mission unencumbered by regulatory fines, restricted access, and negative public reactions.

The mission of the Compliance Technology Thrust Area is to conduct research and development to support waste treatment and disposal, environmental monitoring, marine risk assessment, and environmental management that is not directly related to site restoration but related to meeting current and future environmental compliance requirements of DoD and DOE. It also includes end-of-pipe recycling (i.e., waste that is reused for other than its original purpose). Further, it addresses understanding the fate and transport of defense-related air and wastewater discharges. It does not include elimination of waste streams through substitution or process modification. These are included in Pollution Prevention.

Principal Driving Requirements

The primary concerns in this technology thrust area include: loss of operational capability, the cost of regulatory compliance, and significant legal requirements. Each uniformed Service has submitted its User Requirements for Compliance, which are prioritized in the DoD Environmental Technology Requirements Strategy. These primary DoD environmental concerns reflect the need to:

- Better characterize DoD wastes and pollutant behavior;
- Control and monitor air and wastewater discharges;
- Develop improved fate and transport prediction capabilities for discharges;
- Minimize and control shipboard and land-based sources of solid waste (including plastics);
- Develop effective treatments of hazardous waste; and
- Monitor and control noise generation and propagation.

Compliance issues are addressed by the following four major subthrust areas related to affected environmental media: Air, Water, Solid, and Noise. These media are further categorized into specific types of pollutants, monitoring actions, or processes as illustrated in Figure III-4.

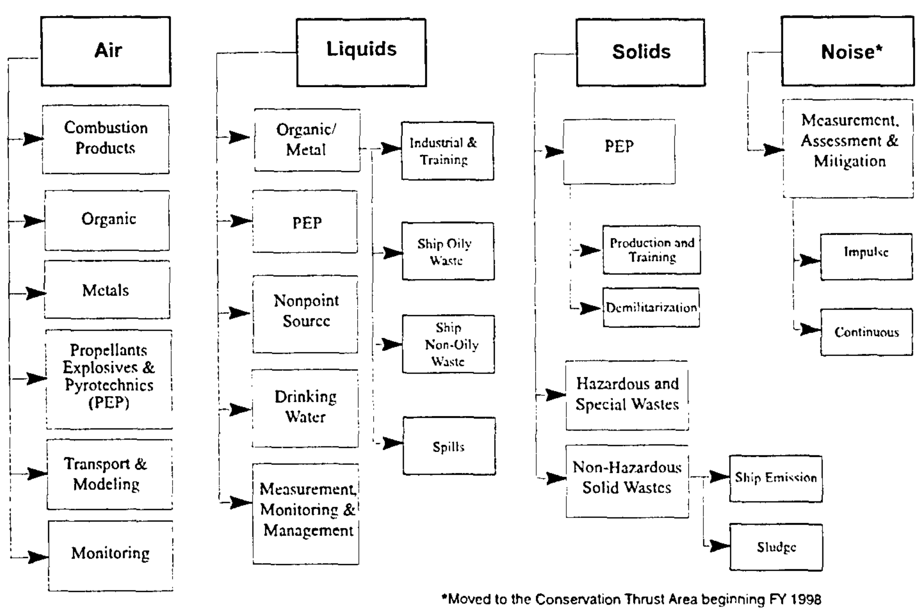


Figure III-4. Compliance Taxonomy

Military operations, training, and manufacturing activities can be severely restricted if they do not comply with existing environmental regulations. In the course of implementing the Clean Air Act Amendments (CAAA) of 1990, a number of local air quality jurisdictions (many facing non-attainment status for one or more priority pollutants) have imposed local standards that are more stringent than the national emission standards. Military-unique systems (e.g. liquid-fuel rockets, military jet engines, and mobility equipment) will require that DoD control emissions of oxides of nitrogen (NOx) and hazardous air pollutants (HAP), including volatile organic compounds (VOC), at DoD installations. These emissions frequently are episodic (e.g., jet engine test cells; painting, stripping and cleaning operations).

Existing Clean Air Act regulations and anticipated future restrictions on NOx/HAPs/VOCs are testing the limits of existing emissions control technology which suffer from significant drawbacks (e.g., a reduction in realized power). Without new technology, the curtailment of missions, closing of facilities, and assessment of fines are real possibilities.

The environmentally-safe disposal of the huge stockpile of munitions and propellants accumulated by all parties during the Cold War present a substantial challenge worldwide. More than 60 percent of these materials are not amenable to disposal by disassembly, recycling or incineration. Therefore, disposal by burning and detonation is the only means applicable, a relatively simple and cost effective method for stockpile reduction but one that can generate excessive air pollutants. Concerns about the short and long term impacts of OB/OD activities on the health of humans and ecosystems have severely restricted and sometimes prohibited OB/OD in the U.S. and many other countries.

Lead-based paint has been used on more than 1 billion square feet of DoD structures and buildings including more than 200,000 DoD family housing units in the continental United States and 22,000 in Hawaii. Lead-based paint is a potential hazard to occupants, especially children below the age of 6 years. The cost of removal of lead-based paint from DoD structures and buildings is estimated to be more than $1 billion and presents a health hazard to remediation workers using current technology.

The Clean Water Act of 1977 prohibits the discharge of untreated sewage (blackwater) by ships in navigable waters. Shipboard graywater is the product of hotel and commissary-type activities aboard U.S. Navy ships. Common sources of graywater are showers, sinks, and galley and scullery equipment. No graywater holding capacity has been required for U.S. Navy ships with the exception of operations within the Great Lakes. However, with anticipated tightening of global wastewater discharge regulations, the Navy has identified the need to develop technologies that are appropriate for the control and treatment of combined shipboard graywater and blackwater (i.e., non-oily wastewater) as one of their environmental priorities. Further, DoD must meet international environmental regulations for the disposal of solid waste and plastics at sea. To address this need, the Navy must develop compact, efficient equipment for the destruction of solid waste onboard DoD vessels.

Preservation of training, testing and readiness requires that DoD be capable of controlling, assessing, managing and monitoring noise impacts in the vicinity of its bases and installations. It is becoming increasingly difficult to consistently meet this objective. The direct impact is a loss of training and readiness capability through the closure of ranges and firing points, altered flying routes, less realistic training

procedures, and nighttime curfews. DoD has lost significant mission capability at over 50 installations as a result of noise impacts.

Figure III-5 shows the funding by subthrust area. For FY 1997, Compliance received approximately 17 percent of the total SERDP budget. Further, at the end of FY 1997 SERDP has shifted all noise related research to the Conservation Technology Thrust Area as most noise impacts are either related to their effects on threatened and endangered species or their effects on cultural artifacts. In FY 1998 and beyond, a slight decrease in SERDP's Compliance Technology Thrust Area investment is anticipated, although this could change with the implementation of new environmental regulations. Congress appropriated funds in FY 1997 and FY 1998 specifically to conduct efforts in support of cleanup worker health and safety training aspects. This project is represented under "Other" category in Figure III-5.

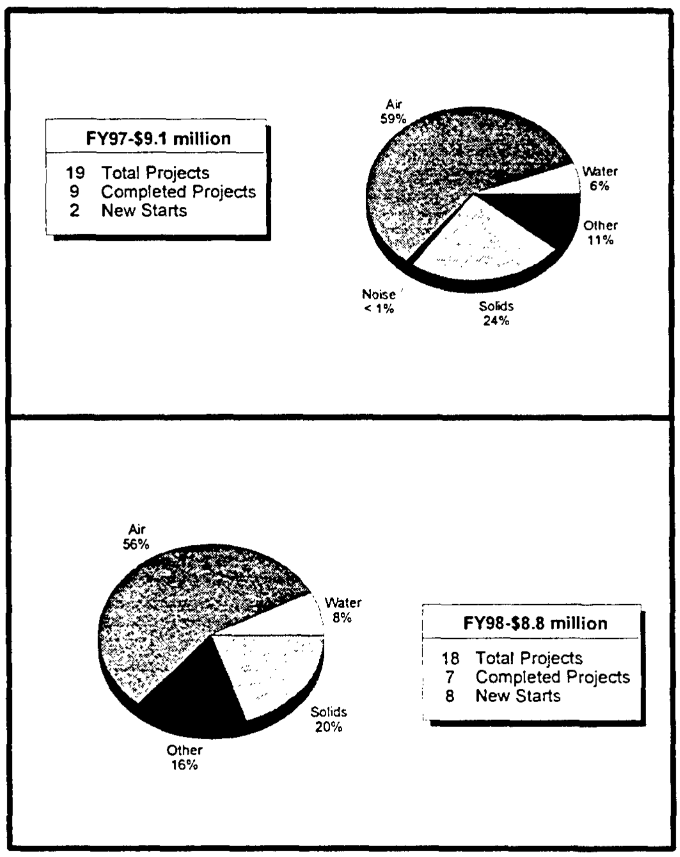


Figure III-5. SERDP Compliance Funding, FY 1997-FY 1998

Leveraging with other Defense science and technology programs and industry, the Compliance Technology Thrust Area focuses on the following research and development objectives:

- Develop control, treatment and disposal technologies for ship operations (bilge, grey/black wastewater, solid waste, and air emissions);
- Develop environmentally and economically acceptable disposal alternatives to open burning or open detonation of propellants, munitions and energetic materials;
- Develop new control, treatment and disposal technologies for hazardous wastes resulting from manufacturing, maintenance and industrial operations, and installation support operations (waste water, solid waste and air emissions);
- Develop control and monitoring techniques for non-energy related air toxic emissions to include development and testing of models to predict emissions of, and exposures to, pollutants from Defense facilities and to design effective, multimedia environmental management strategies;
- Develop management and mitigation technologies for noise pollution;
- Develop improved monitoring, characterization and assessment tools related to environmental compliance and management; and
- Develop standardized risk assessment methods, protocols, models and data for air and waste water discharges and noise related to defense activities.

Compliance Program

The following list reflects FY 1997 completed projects and projects continuing into FY 1998. Also included are titles of projects commencing in FY 1998. Complete descriptions of all of the projects for FY 1997 and FY 1998 may be found at the listed page numbers in Appendix B - Compliance Project Summaries.

Subthrust 1 - *Air*

Page

FY 1997 Completed Projects

Emission Reduction Planning Model B-6
Metal Perovskite Catalysts for NOx Reduction B-8
Characterization of Open Burning/Open Detonation Emissions B-11
Measuring and Modeling for OB/OD Permitting B-14
Vapor Permeation VOC Recovery from Refueling and Storage Operations B-15

FY 1998 Continuing Projects

Reduction of NOx Emissions from Marine Power Plants B-4
Advanced Mass Spectrometry for Atmospheric Monitoring B-9
Lead-Based Paint Hazard Mitigation B-19
Development of Non-Thermal Plasma Reactor Technology for Control of Atmospheric Emissions B-27
Development and Integration of Laser-Based Sensors for VOC/NOx and Metals Emissions Monitoring B-29
Detect and Identify Multiple Hazardous Air Pollutants (HAPs) at Extended Distances . . . B-31

FY 1998 New Start Projects

Plasma-Assisted Catalytic Reduction of NOx B-33
Optimization of an Innovative Biofiltration System as a VOC Control Technology for Aircraft Painting Facilities B-39
Membrane-Mediated Extraction and Biotreatment of VOCs B-41
Characterization of Particulate Emission: Size Characterization and Chemical Speciation B-43

Subthrust 2 - *Water*

FY 1997 Completed Projects

Leak Location in Underground Pipelines B-13

FY 1998 Continuing Projects

Kinetics of Supercritical Water Oxidation B-17

FY 1998 New Start Projects

Electrochemical Advanced Oxidation Process for Shipboard Final Purification of Filtered Black Water, Gray Water, and Bilge Water B-45
Novel Nonporous Fouling - Resistant Composite Nanofiltration Membranes and Membrane Separation Systems for Wastewater Treatment B-47

Subthrust 3 - *Solid*

FY 1997 Completed Projects

Laser Ablation/Ionization Characterization of Solids B-16
Evaluation of the Use of Waste Energetics as Supplemental Fuels B-22

FY 1998 Continuing Projects

Compact, Closed-Loop Controlled Waste Incinerator B-2
Demonstration of Compact, Closed Loop Controlled Waste Incinerator B-25

FY 1998 New Start Projects
Enzymes for Degradation of Energetic Materials and Demilitarization Of Explosives Stockpiles B-35
Hypergolic Non-Detonative Neutralization in Production and Demilitarization B-37

Subthrust 4 - *Noise*

FY 1997 Completed Projects
Controlling, Assessing, Managing, and Monitoring the Noise Impact from Weapons, Helicopters, and Aircraft on Training B-21

FY 1998 Continuing Projects
None

FY 1998 New Start Projects
None

Other

FY 1998 Continuing Project
National Environmental Education and Training Center (NEETC) B-23

FY 1999 Compliance Initiatives

Controlling and reduction of particulate matter emissions is an issue having significant visibility. SERDP's initiative to identify **Methods of Controlling Fine Particulate Matter** seeks to develop new emission-control technologies for airborne particulate matter from combustion sources with strong emphasis on particulate matter less than 2.5 microns (PM2.5). This technology is required to control fine particulate matter (PM) in air as may be emitted from combustion sources such as jet engines exhaust during tests and operations, ground vehicle and equipment operation, and/or boilers (gas discharges). Whereas lowering the ozone standard simply aggravates an existing VOC-compliance challenge, the new proposed PM2.5 standard drastically lowers the effective regulatory limit for particulate matter from DoD's operational and industrial processes. Providing an armory of compliant, cost-effective control methods to complement possible process improvements and selective force reductions is the target of this activity.

The FY 1999 initiative on **Oil/Water Separators** is designed to promote innovative technologies to separate oil from water while processing wastewater generated by DoD weapons and support systems. The oil/water separators that are presently in use rely on old technology. The oily components may contain sludges consisting of organics, particulate matter, and, in some cases, heavy metals. The separators must provide a substantial increase in oil removal efficiency and an equivalent size and a decrease in operator

attention and maintenance. New efficient methods to separate oils and oily components from water will result in significant savings in the ability to return more water quicker and cleaner for reuse or to the environment. They should also result in a significant reduction in labor hours expended in cleaning the separators.

A by product of the oil/water separation process is sludge that is difficult to dispose of and treat. SERDP is soliciting ideas for the **Treatment of Oil/Water Separator Sludge** that will result in development of innovative candidates for environmentally benign, non-labor-intensive methods to treat oil-contaminated oil/water separator sludges. Separator sludge contains organics, particulate matter, and, in some cases, heavy metals. In gravity separators it accumulates in the bottom of the separator and in coalescent separators it also accumulates on the coalescing media. This sludge interferes with the ability of the separator to remove oil and increases maintenance requirements. While treatment of the sludge is the primary focus of this work, volume reduction of heavy metal contaminated sludge is also of interest. Primary focus shall be given to on site treatment of sludge from separators. In addition, methods to easily remove sludge from separators with subsequent treatment also will be developed. A new method to treat sludge on site should also reduce the downtime of separators due to sludge build-up which results in decreased maintenance requirements. Increased sludge removal should increase the oil removal efficiency and life of the separators.

Detailed descriptions of the FY 1999 Compliance Statements of Need may be found in Appendix E.

CONSERVATION

Introduction

The Defense Department's Conservation goals are to conserve, protect, enhance, and manage the natural and cultural resources under its control in a manner consistent with its military mission, while simultaneously complying with all laws and regulations and providing optimal use of these resources. Knowledgeable, proactive management of natural resources is critical because the natural environment provides the realistic training environment in which to exercise and test the capabilities of the military forces. Several Federal statutes, such as the Sikes Act, The Migratory Bird Treaty Act, the Fish and Wildlife Conservation Act, the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), the National Historic Preservation Act (NHPA), and local laws, regulations, and requirements provide specific stewardship direction for all DoD and DOE lands.

DoD and DOE must be effective stewards of the natural and cultural resources under their direction in a proactive manner. By better understanding the environments in which they operate, the Departments can improve their resource-use decisions to promote conservation, while continuing to fulfill their primary missions. DoD's conservation concerns as depicted in Figure III-6 can be divided into three distinct operating areas where the Department conducts training and testing and therefore impacts the natural environment: air, land, and water (oceans and coastal waterways).

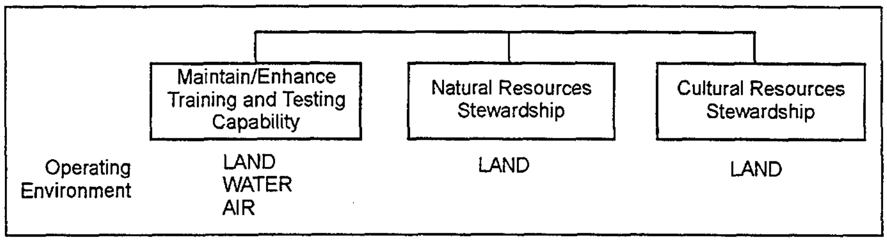


Figure III-6. Conservation Taxonomy

Figure III-7 shows the FY 1998 and FY 1999 funding by subthrust area. For FY 1997, Conservation received approximately 13 percent of the SERDP budget. In FY 1998 and beyond, Conservation funding will gradually grow to support a more sustainable future.

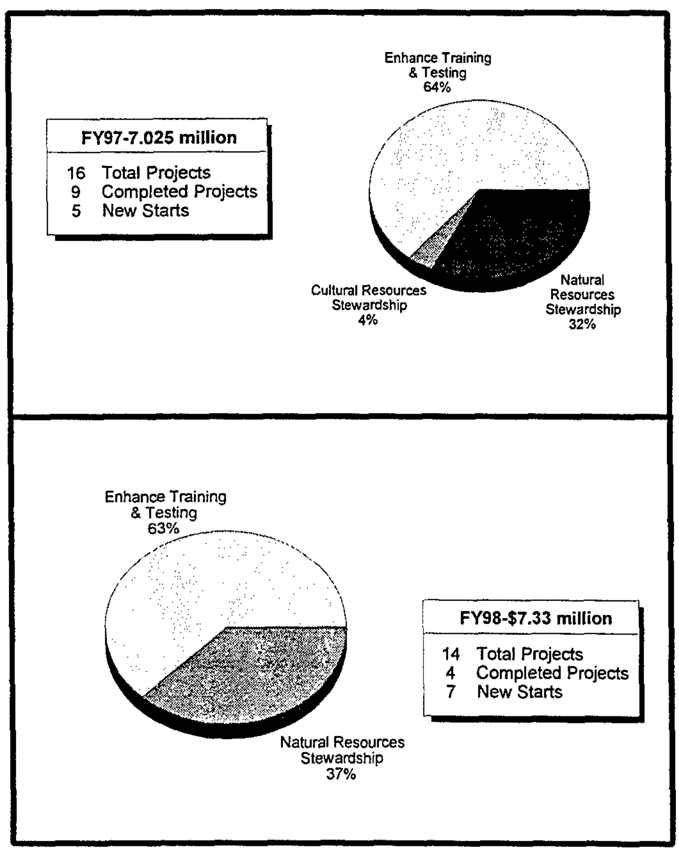


Figure III-7. SERDP Conservation Funding, FY 1997-FY 1998

Principal Driving Requirements

Each uniformed Service has submitted its User Requirements for Conservation, which are prioritized in the DoD Environmental Technology Requirements Strategy. These individual requirements affect all operating environments and can be grouped into three related but distinct principle driving requirements, which are the needs for DoD:

- To maintain and enhance its training and testing capability to ensure military readiness;
- To steward and protect the natural resources under its control; and
- To steward and protect the cultural resources under its control.

In the Land Operating Environment, the Department of Defense (DoD) manages more than 900 installations that collectively comprise about 25 million acres. Installations range in size from more than 300 million acres to less than 10 acres. With broad geographic distribution (largely domestic but some foreign), DoD lands represent a remarkably diverse collection of ecosystem and habitat types, including forests, grasslands, wetlands, and deserts. DoD's ability to conduct realistic training exercises and to test weapon systems and equipment cannot be ensured without responsible stewardship and sensible management and conservation practices.

In the Air Operating Environment, the Air Force is required to assess the impacts of proposed aircraft operations on the environment. Many of the assessments accomplished to date contain unsubstantiated, anecdotal remarks concerning the effects of aircraft noise on wildlife. Quantitative data are needed for environmental planners at the major command and Air Staff levels to defend the Air Force's low altitude Military Training Routes (MTR), which are essential for combat training. The U.S. Fish and Wildlife Service can and has stopped proposed low altitude flight activities through the use of formal Section 7 consultations in accordance with the Endangered Species Act.

In the Water Operating Environment, the Navy must comply with the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), and the Marine Mammal Protection Act (MMPA) in all operations and tests. This is a difficult task when "take" is defined under the MMPA to mean "harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal."

The Departments of Defense and Energy lands are subjected to a wide variety of uses ranging from military training to hazardous waste disposal to timber production. Nevertheless, these lands are often the last large natural areas in otherwise developed environments. As such, they represent valuable resources for preserving the biodiversity of their local regions, and they serve as refuges for a wide variety of threatened and endangered species. Nearly 1,000 species in the U.S. are protected under the Endangered Species Act (ESA), while thousands more are candidates for listing. Over 300 listed and candidate species, in addition to nearly 300 state listed species and species of concern, are known or suspected to reside on military lands. This can lead to mission constraints and impediments to land acquisition, potentially leading to reduced defense readiness; lengthy and costly litigation; and sometimes criminal and civil penalties. DoD's ability to address this issue is limited because of inadequate information on distribution and abundance of

threatened and endangered species (TES) and their habitats on military land, the effects of mission activities on TES and supporting ecosystems, and appropriate mitigation and management options.

Furthermore, military facilities face increasing demands as a result of base closures and realignments, new weapon systems and equipment requiring greater training ranges, additional regulatory constraints, and changes in tactics and doctrine. Training intensity on remaining installations will continue to rise, often preventing full recovery of vegetation between training exercises. Today's training and testing needs lead to changes in the ecosystem that may exceed the current estimated annual cost of $56 million in land repair and maintenance. On-site and off-site environmental impacts, wildlife conservation issues, cultural resources concerns, and the need for training realism all dictate that natural resources must be maintained and enhanced on these installations. The tasks of balancing military land uses, complying with resource regulations, and assessing impacts on the sustainability of both the resource base and the military mission are complex and challenging. Activities to alleviate one problem can often exacerbate others. All too often, decision-makers on military installations are faced with making critical land management decisions without the benefit of complete environmental information nor complete knowledge of other, competing objectives and/or land use requirements.

The current reliability associated with the detection and location of cultural and archeological artifacts is minimal. Once a cultural or archeological resource site is identified, it must then be assessed in order to determine its significance. Currently, the costs associated with Phase II assessments of cultural and archeological resources are quite high. In the Army alone there are approximately 120,000 archeological sites, of which only 10 percent have been assessed and their significance determined. In addition, DoD must comply with the requirements of the Native American Grave Protection and Repatriation Act (NAGPRA), which protects Native American artifacts and cultural items, and the Archeological and Historic Preservation Act, which requires evaluation of proposed activities on the cultural environment. New techniques and capabilities are needed to reduce the costs of compliance and to avoid delays and the possibility of damaging artifacts when an unanticipated but significant discovery occurs at a construction site.

Leveraging with other Defense Science and Technology programs and industry, SERDP focuses on the following Conservation research and development objectives:

- Develop standardized, cost effective methods to inventory, characterize, and monitor natural and cultural resources to help ensure compliance with applicable laws and requirements. Where appropriate, use defense-unique data collection and assessment tools to develop these methods;

- Develop and demonstrate more effective methods and techniques to maximize availability of military lands in support of military missions, with minimal impact to natural and cultural resources in a manner consistent with the Services' mission and Federal environmental regulations;

- Develop and demonstrate efficient and effective techniques to proactively conserve and restore natural and cultural resources, particularly threatened and endangered species and the ecosystems on which they depend;

- Develop and demonstrate effective, user-friendly computer-based models to determine the incremental and cumulative impact of military activities on natural and cultural resources, and assess effectiveness of conservation and restoration techniques;

- Develop state-of-the-art techniques to assess and predict the impact of military use on those critical elements of the ecosystem impacting biodiversity; and

- Develop the needed methods, tools, guidelines, and decision support systems for effectively implementing integrated resource management techniques.

Conservation Program

The following list reflects FY 1997 completed projects and projects continuing into FY 1998. Also included are titles of projects commencing in FY 1998. Complete descriptions of all of the projects for FY 1997 and FY 1998 may be found at the listed page numbers in Appendix C - Conservation Project Summaries.

Subthrust 1 - *Maintain/Enhance Training/Testing Capability*

Page

FY 1997 Completed Projects

The Effects of Aircraft Overflights on Birds of Prey C-4

FY 1998 Continuing Projects

Whale Monitoring Using IUSS C-2

Digital Terrain Modeling and Distributed Soil Erosion Simulation/Measurement for Minimizing Environmental Impacts of Military Training C-11

Development and Demonstration of a Risk Assessment Framework for Natural Resources on Military Training and Testing Lands C-17

Marine Mammal Responses to Low Frequency Sound C-21

FY 1998 New Start Projects

Information Technology Tools for Assessment and Prediction of the Potential Effects of Military Noise on Marine Mammals C-23

Assessment of Training Noise Impacts on the Red-Cockaded Woodpecker C-24

Improved Units of Measure for Training and Testing Area Carrying Capacity Estimation C-31

Identify Resilient Plant Characteristics and Develop a Wear Resistant Plant Cultivar for Use on Military Training Lands C-33

Subthrust 2 - *Natural Resources Stewardship*

FY 1997 Completed Projects

Ecological Biomarkers: Monitoring Wildlife Fauna at DoD Installations C-5
Genetic Diversity Monitoring in Plants and Wildlife C-6
Integration of Radiotelemetry, Remote Sensing and GIS C-7
Strategic Natural Resource Management Methodology C-8
Advanced Biotelemetry for Resource Management C-16
Freshwater Decision Makers' Information Needs C-25
Land Management Systems C-26

FY 1998 Continuing Projects

Threatened, Endangered, and Sensitive Resources C-9
Ecological Modeling for Military Land Use Decision Support C-14
Analysis and Assessment of Military and Non-Military Impacts on Biodiversity: Framework for Environmental Management on DoD Lands Using Mojave Desert as a Regional Case Study C-19

FY 1998 New Start Projects

Error and Uncertainty Analysis for Ecological Modeling and Simulation C-27
Emerging and Contemporary Technologies in Remote Sensing for Ecosystem Assessment and Change Detection on Military Reservations C-28
Predicting the Effects of Ecosystem Fragmentation and Restoration: Management Models for Animal Populations C-29

Subthrust 3 - *Cultural Resources Stewardship*

FY 1997 Completed Projects

Phased Array Acoustic Detection of Artifacts C-13

FY 1998 Continuing Projects

None

FY 1998 New Start Projects

None

FY 1999 Conservation Initiatives

There is one FY1999 proposed new initiative in Conservation's Maintain/Enhance Training and Testing subthrust area and one new initiative planned in the Cultural Resources Stewardship subthrust area. In the training and testing area, SERDP plans a new effort in the area of **Mitigation/Rehabilitation of Damage Caused By Military Training and Testing Impacts**. The intent of this statement of need is two-fold: (a) to focus on innovative technologies for mitigation and/or rehabilitation of damage resulting from military

training and testing impacts and (b) to identify rehabilitation and maintenance techniques that will provide general improvement of the resiliency of ecosystems for long-term sustainment of lands. Conceptually, the sustainability of lands for continued use requires short- and long-term techniques. Damage caused by the military use of lands can be direct and subtle. Direct damage results in immediate or short-term removal of vegetation, subsequent gullying, and potential impacts on water quality. Continued damage and natural ecosystem processes can ultimately affect ecosystem structure and functions, e.g., habitats, biogeochemical cycles, water quality, etc. Work proposed for this SON should identify land rehabilitation techniques that apply to either or both long- and short-term effects. Differences (or similarities) in restoration approach need to be assessed, and rehabilitation design and implementation actions need to be determined that are most appropriate when considering both the short-term needs to train realistically and minimize environmental impact today, and the long-term needs to sustain ecological resources for future use.

The objective of **Cultural Resources Management Detection and Evaluation Technologies** is to improve the identification and assessment of prehistoric, historic, and traditional cultural properties and sites on Department of Defense (DoD) and Department of Energy (DOE) lands. There is a need to identify, develop, and integrate advanced and emerging technologies to more efficiently and cost-effectively identify and evaluate cultural resources. In addition to survey and assessment technologies, techniques are necessary for the efficient management of information that exploits the cumulative output of technologies. This would include both relational and spatial information. This information could include archaeological, historical, sociocultural and ecological information in addition to large sets of complex geospatial data. The information should not be limited to data exclusively derived from traditional survey, evaluation and mitigation projects. There is also a need to share analytical tools, standards, data, and other management resources among the largest possible community of users.

The product(s) resulting from this SON should fuse such tools or prototypes that will allow for the effective prediction of sites and provide noninvasive tools to adequately assess the significance of these sites. This should include tools to explore the near surface substrates within the context of the larger remotely sensed spatial and spectral landscape, as well as harness rapid and more efficient surveying, mapping, recording, and data analysis procedures. It should purposely and resourcefully exploit available and new digital information from whatever sources that may be useful for solving cultural resource management requirements. These requirements include DoD responsibilities to manage resources subject to the Native American Graves Protection and Repatriation Act (NAGPRA) and traditional cultural properties and historic features routinely considered in the National Historic Preservation Act (NHPA).

The Management-Scale Ecosystem Research Workshop identified a critical need for scientific information to support an ecosystems management approach, especially as it relates to mission concerns. The success of user ecosystems management plans will depend on the capabilities and increased knowledge generated by research investment. In 1999, the SERDP Ecosystem Management Program (SEMP) will initiate a number of studies to allow a full array of remote sensing, ground truth experiments, modeling, cause-effect studies, etc. to be integrated to address complex problems. These studies will focus on improving scientific understanding of the impacts of biogeochemical cycles and biological diversity on ecosystems. Statements of Need are not yet available.

Detailed descriptions of the FY 1999 Conservation Statements of Need may be found in Appendix E.

POLLUTION PREVENTION

Introduction

The Pollution Prevention Technology Thrust Area focuses on reducing or eliminating the generation of pollution within the DoD. The application of pollution prevention technologies will positively influence the other DoD environmental Thrust Areas by encouraging the use of innovative technologies and practices such as recycle, recovery and reuse, reducing pollutants to be managed at the source, and promoting the sustainable use of natural resources.

As defined under the Pollution Prevention Act of 1990, pollution prevention means "source reduction" and other practices that reduce or eliminate the creation of pollutants through increased efficiency in the use of raw materials including energy, water and other resources, or materials substitution. Source reduction is defined as any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment or disposal. Source reduction does not include energy recovery, treatment, disposal, or end-of-pipe recycling if the waste is used for other than its original purpose. SERDP Pollution Prevention does address end-of-pipe recycling of wastes, if used for the same purpose. For example, munitions and their materials may be recycled for production of new munitions.

Waste minimization programs in the commercial sector have demonstrated that pollution prevention saves money. Clearly, pollution prevention in areas not being adequately addressed by private sector practices will be a key approach for DoD and DOE to meet their environmental obligations in a cost effective manner. Material substitutions, manufacturing process changes, inventory and stockpile controls, and adjustments to routine, daily processes will be required to meet these obligations.

The DoD and DOE have a number of unique functions, such as the development and operation of sophisticated weapons systems which demand specialized, high-performance materials. Many of these materials are the same toxic chemicals that are targeted for voluntary reduction. The challenge to DoD and DOE is to find new high-performance materials that are not toxic, and/or to determine innovative ways to control use of toxic chemicals in order to reduce releases and off-site transfers.

The Air Force, Army, and Navy have each submitted their Pollution Prevention User Requirements, which are prioritized in the DoD Environmental Technology Requirements Strategy. These requirements can be grouped into environmental concerns. The primary DoD environmental concerns in Pollution Prevention are the needs to:

- Identify alternatives for hazardous and toxic chemicals/materials;
- Reduce the use of hazardous and toxic chemicals/materials;
- Reduce the volume and toxicity of wastes and pollutants through source reduction;

- Improve the efficiencies of mechanical and chemical systems;
- Incorporate environmental ramifications as key evaluation considerations in major system design and acquisition; and
- Consider the life-cycle effects of materials and systems.

These Defense Pollution Prevention needs are addressed by the four major subthrust areas of Air, Water, Solids, and Modeling and Databases, which are further organized along process lines as depicted in Figure III-8.

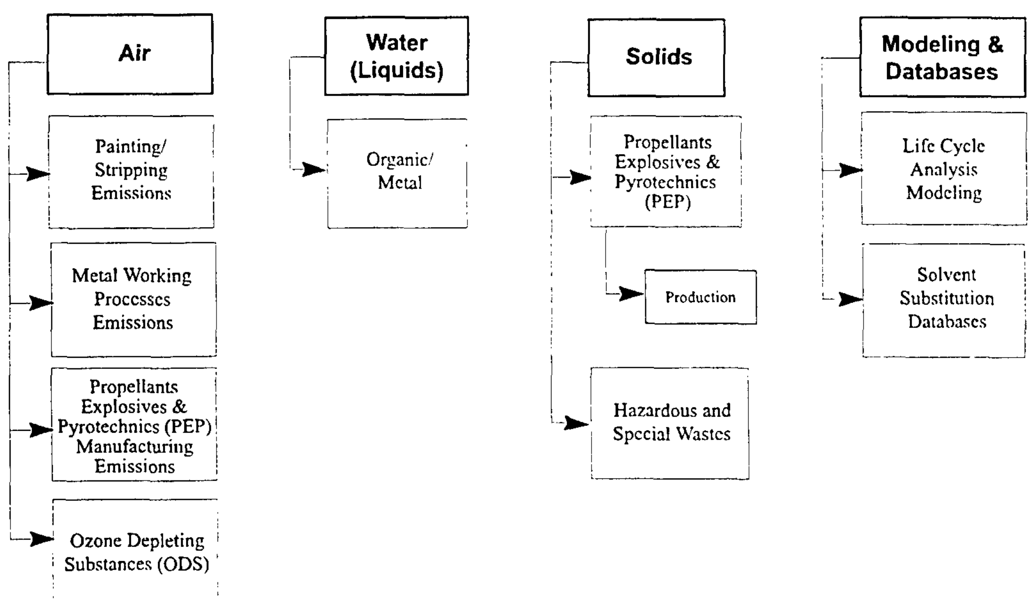


Figure III-8. Pollution Prevention Taxonomy

The FY 1997 and FY 1998 distribution of SERDP funding for Pollution Prevention among the subthrust areas is shown in Figure III-9. For FY 1997, Pollution Prevention received approximately 30 percent of the SERDP budget. In the out years, Pollution Prevention will grow relative to the three other technology areas of SERDP in order to meet defense users' demands for better, less costly, and cleaner weapons systems and processes.

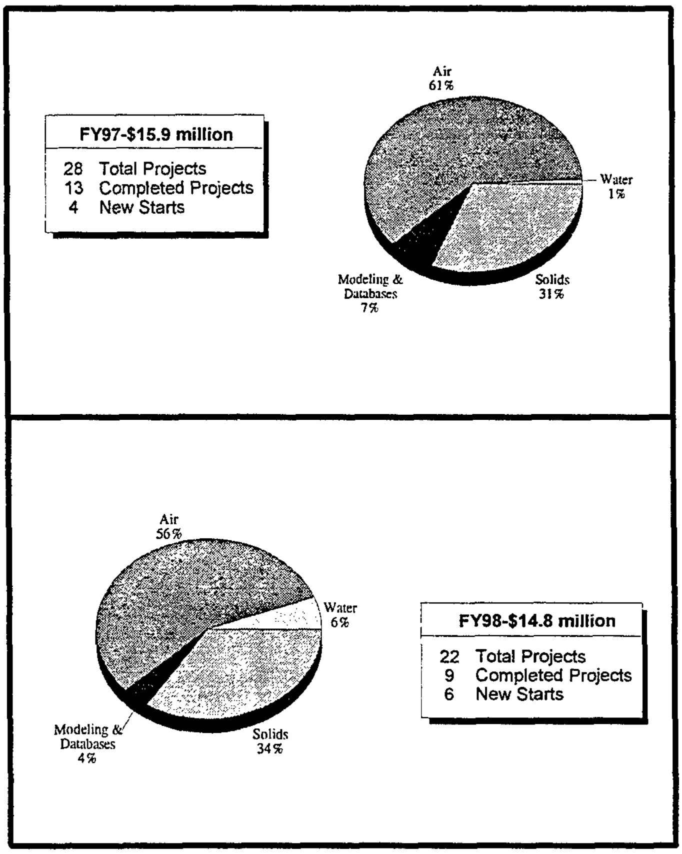


Figure III-9. SERDP Pollution Prevention Funding, FY 1997-FY 1998

Principal Driving Requirements

Executive Order 12856, "Federal Compliance with Right-to-Know Laws and Pollution Prevention Requirements," states that the Federal Government should become the leader in the field of Pollution Prevention through the management of its facilities, its acquisition practices, and supporting the development of innovative pollution prevention programs and technologies. The Executive Order challenges the heads of the Departments of Defense and Energy to set goals voluntarily to reduce their agency's total releases of toxic chemicals to the environment and off-site transfers by 50 percent from 1994 baseline figures by December 31, 1999.

Virtually all of DoD maintenance and repair activities involve the use of toxic or hazardous substances. The 1990 Clean Air Act Amendment (CAAA), the Resource Conservation and Recovery Act (RCRA), and state and local regulations restrict the emission and disposal of these hazardous materials. Ozone depleting

substances (ODSs) are being phased out of production under national policy and international (Montreal) protocol. DoD directives require significant reductions in hazardous wastes and development of alternative materials and processes that meet environmental restrictions and allow DoD to continue operations. Operations and training activities at DoD installations and facilities generate large quantities of hazardous, non-hazardous, and special wastes that are expensive to manage and dispose.

During this decade, an increasing emphasis has been placed on pollution prevention to reduce environmental impacts associated with DoD weapon systems acquisition. The DoD Pollution Prevention Strategy of August 11, 1994 established a goal to identify and develop environmental life cycle cost estimating tools that inject pollution prevention and other environmental concerns into acquisition decisions. Development and application of modeling and simulation tools to identify and test technical solutions which reduce reliance on toxic materials and processes are required.

Leveraging with other DoD, DOE, and EPA science and technology programs and industry, the Pollution Prevention subthrust areas focus on the following research and development objectives:

- Alternative materials and processes to replace defense uses of hazardous heavy metals (e.g. chromium, cadmium, lead, nickel) and metallic compounds, and hazardous air pollutants;
- Alternatives to volatile organic compound (VOC) coatings, adhesives, sealants and lubricants that are not being adequately addressed by industry;
- Alternatives to hazardous and toxic chemicals for surface cleaning, degreasing and paint stripping;
- Alternatives to hazardous and toxic chemicals, especially ozone depleting substances (ODS), used in climate control, refrigeration, as solvents, and as fire-fighting agents;
- Techniques to regenerate, recycle, re-use, and stockpile defense unique toxic chemicals and materials;
- On-line sensors and monitoring systems to prolong usefulness of toxic chemicals in defense operations such as plating, stripping, and mechanical maintenance;
- Cost-effective, environmentally preferable packaging and recycling approaches to reduce generation of solid waste from defense-related operations; and
- Predictive models (which include environmental life cycle costing) to aid in the development of environmentally sound weapon systems and platforms during concept development, design, test and evaluation, maintenance (logistics support documentation), and decommissioning.

Pollution Prevention Program

The following list reflects FY 1997 completed projects and projects continuing into FY 1998. Also included are titles of projects commencing in FY 1998. Complete descriptions of all of the projects for FY 1997 and FY 1998 may be found at the listed page numbers in Appendix D - Pollution Prevention Project Summaries.

Subthrust 1 - *Air*

Page

FY 1997 Completed Projects

Aircraft Maintenance Chromium Replacement D-6
Solvent Substitution and Low VOC Cleaners D-7
Alternate Electroplating Technology D-8
Aircraft Depainting Technology D-9
Encapsulated Micron Fire Suppression Technology D-10
Solid State Metal Cleaning D-11
Large Area Powder Coating D-12
Fluorinated Ship-Hull Coatings for Non-Polluting Fouling Control D-24

FY 1998 Continuing Projects

Organic Protective Coatings and Application Technology D-4
Laser Cleaning and Coatings Removal D-13
Advanced Fire Fighting Streaming Agent D-14
Trapped Vortex Combustor for Gas Turbine Engines D-29
Low VOC Chemical Agent Resistant Coatings (CARC) D-33
Next-Generation Fire Suppression Technology Program D-39

FY 1998 New Start Projects

Tri-Service "Green" Gun Barrel - A Physical Vapor Deposition for the Application of Environmentally Safe Coatings for Gun Barrel Bore Protection D-43
Sol-Gel Technology for Low VOC, Non-Chromated Adhesive & Sealant Applications . . D-53

Subthrust 2 - *Water*

FY 1997 Completed Projects

Acid Recycle D-19

FY 1998 Continuing Projects

None

FY 1998 New Start Projects

Genetic Enhancement of an Anti-Freeze Protein for Use as a Substitute for Ethylene Glycol for Aircraft Deicing D-47
Environmentally Advantaged Substitutes for Ethylene Glycol for Aircraft Ice Control . . . D-49

Subthrust 3 - *Solid*

FY 1997 Completed Projects

DoD/DOE Clean Agile Manufacturing of Energetics D-2
High-Performance, Lead-Free Electrical Sealants D-20
Insensitive Munitions D-42

FY 1998 Continuing Projects

Laser Ignition to Replace Chemical Ordnance Igniters for Propulsion D-21
Recycling Propellants in Nonpolluting Supercritical Fluids: Novel Computational Chemistry Models For Predicting Effective Solvents D-23
Solventless Pyrotechnic Manufacturing D-25
Solventless Manufacture of Artillery Propellant Using Thermoplastic Elastomer Binder . . D-27
Eliminate Toxic and VOC Constituents from Small Caliber Ammunition D-35
Elimination of Toxic Materials and Solvents from Solid Propellant Components D-37

FY 1998 New Start Projects

Non-Polluting Composites Remanfacturing and Repair for Military Application D-45
Recycle and Reuse of Industrial Rags Using Liquid CO_2 and Surfactant Additives as a Cleaning Agent D-51

Subthrust 4 - *Modeling & Databases*

FY 1997 Completed Projects

Integrated Expert Solvent Substitution Data Base D-18

FY 1998 Continuing Projects

Life Cycle Engineering and Design Program D-16
Pesticide Reduction through Precision Targeting D-31

FY 1998 New Start Projects

None

FY 1999 Pollution Prevention Initiatives

SERDP is proposing six New Start initiatives, all in the Air subthrust area:

In order to produce a superior coating, the fundamental understanding of what makes a coating superior is required. Two initiatives are directed to increase the fundamental understanding of the coating chemistry and degradation process. **Mechanisms of Coatings Degradation** will focus on developing innovative technological tools to acquire a fundamental understanding of the mechanisms by which coatings degrade. These mechanisms refer to the changes in chemical, physical and mechanical properties which occur in coatings during their lifetime thereby contributing to the loss or degradation of performance. Performance may be in terms of signature, weather protection and/or corrosion abatement. This program should result in a basic understanding of degradation mechanisms as well as recommended approaches for the development and optimization of new coating systems and realistic life prediction techniques.

Mechanisms of Chromate Corrosion Protection: This program intends to develop tools to acquire a fundamental understanding of the chemical and/or physical processes and mechanisms of corrosion protection that occur when chromate-based coatings are applied on metal surfaces. A knowledge of corrosion mechanisms and chromate passivation will provide a rational basis for design, selection and evaluation of new environmentally friendly replacements for chromate corrosion inhibitors and support the development of a deterministic basis for predicting substrate corrosion rates. The use of chromates as corrosion inhibitors has evolved empirically over several decades, however, a molecular level understanding of the chemical/physical mechanism(s) by which they operate has never been attained. Not only is it unclear exactly what role chromates play, it is not known what chromate replacement complexes need to do to ensure long-lived coating systems.

Nondestructive Evaluation of Cracking and Corrosion Under Coatings is an initiative that will focus on the development of realistic and practical nondestructive inspection (NDI) technologies for "inspection-through-paint." Currently, the need to inspect substrates for corrosion, fatigue cracks and other damage often requires the removal and replacement of the coating system long before its potential service life is achieved. If the substrate could be evaluated without damaging an intact coating system, the number of stripping and repainting cycles could be reduced. If this could be achieved, environmental pollution resulting from hazardous paint strippers and volatile organic compounds released into the atmosphere by the continuous cycle of stripping/re-painting would be dramatically reduced. Thus, the successful development of NDI technologies will benefit the DoD by: 1) successfully extending the service life of coatings systems, and aging weapon systems, 2) meeting increasingly stringent environmental requirements, and 3) increasing operational capability with limited assets.

Often times the defense depots use extensive and sometimes unnecessary measures to ensure a surface is properly prepared prior to coating. **Cleaning Verification Techniques** will focus on the development of surface cleanliness analysis technologies. These may include the development of new or the modification of existing equipment, technology or procedures. The new technique(s) should be able to: (1) operate in real-time, such that it is useful in process monitoring and control; (2) provide qualitative and quantitative output for comparative assessment of cleanliness levels (both quantitative amounts and species present); (3) handle a wide variety of military specific applications, such as repair and remanufacturing processes

at repair depots; and (4) measure cleanliness levels such that they can be related to required materials property requirements for various surface preparation processes (e.g., repair or application of protective coatings) .

SERDP has two initiatives to deal with elimination of VOCs in sealants and adhesives. **Elimination of High VOC Primers used with Room Temperature Vulcanizing (RTV) Sealants** will focus on developing and/or identifying innovative candidates for VOC compliant primers for use with RTV silicone sealants and/or a primerless RTV silicone. Ideally, the new materials will be drop-in replacements for the current high VOC primers. This will eliminate approximately 10,000 gallons of primer annually, which will result in the reduction of 56,000 pounds of VOCs annually. Successful candidates must meet minimum performance requirements in the following key areas: environmental; toxicology; and physical property performance and materials compatibility.

VOC Compliant Non-Structural Adhesives will focus on developing and/or identifying innovative low/no-VOC, non-structural adhesives to substitute for the current high VOC non-structural adhesives used in military applications. Non-VOC containing materials are preferred over VOC compliant materials. This will eliminate approximately 172,800 pounds of VOC releases annually. Successful candidates must meet minimum performance requirements in the following key areas: environmental; toxicology; physical property performance; and materials compatibility.

Detailed descriptions of the FY 1999 Pollution Prevention Statements of Need may be found in Appendix E.

APPENDIX A
Cleanup Project Summaries

ID#	Project Title	Page
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715	Explosives Conjugation Products in Remediation Matrices	A-20
720	Federal Integrated Biotreatment Research Consortium: Flask to Field Initiative	A-22
729	Accelerated Tri-Services SCAPS Sensor Development	A-25
770	Environmental Risk Assessment Program (ERAP)	A-27
861	NETTS Program - McClellan AFB, CA	A-28
863	NETTS Program - Naval Construction Battalion Center (CBC), Port Hueneme, CA	A-30
864	NETTS Program - former Wurtsmith AFB, MI	A-32
866	NETTS Program - Dover AFB, DE	A-34
886	Bioremediation of Energetic Materials	A-36
1043	Natural Attenuation of Explosives in Soil and Water Systems at DoD Sites	A-37
1049	Application of Neural Networks Coupled with Genetic Algorithms to Optimize Soil Cleanup Operations in Cold Climates	A-39
1052	Multisensor Data Fusion for Detection of Unexploded Ordnance	A-41
1062	Development of Simulators for In-Situ Remediation Evaluation, Design, and Operation	A-43
1064	Bioenhanced In-Well Vapor Stripping to Treat Trichloroethylene	A-45
1070	Low-Frequency Ultra-Wideband Boom Synthetic Aperture Radar (Boom-SAR) for Remote Detection of Unexploded Ordnance	A-47
1071	Unexploded Ordnance (UXO) Detection by Enhanced Harmonic Radar	A-49
1073	Using Mode of Action to Assess Health Risks from Mixtures of Chemical/Physical Agents	A-51
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1081	Genosensor-Based Ecotoxicity Response Assessment	A-55
1084	Selective Removal of Heavy Metals from Aqueous Wastes by Electrosorption on Functionalized Carbon Aerogels	A-57
1089	Negative Ion Sensors for Real-Time Downhole DNAPLs Detection	A-59

1090 Integrated Geophysical Multi-Sensor Detection of DNAPL Source Zone Identification A-61
1091 Innovative Seismic System for Buried Unexploded Ordnance Detection and Classification A-63
1092 Model-Based Data Fusion and Discrimination of UXO in Magnetometry and EM Surveys A-65
1093 In-Situ Clay Formation: A New Technology for Stable Containment Barriers A-67
1094 Environmental Impacts to the Chemical Signature Emanating from Buried UXO A-69
1095 Assessment and Prediction of Biostabilization of Polycyclic Aromatic Hydrocarbons (PAHs) in Sediments A-71

PROJECT SUMMARY

PROJECT TITLE & ID: Rapid Detection of Explosives and Other Pollutants; CU-28

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Research Laboratory - Washington, D.C.

PRINCIPAL INVESTIGATOR: Ms. Anne Kusterbeck

FY 1997 COMPLETED PROJECT

OBJECTIVE: The Department of Defense (DoD) has more than 1,200 sites contaminated with explosives and 87 percent of these exhibit contamination in the groundwater. Remediation of munitions sites contaminated with explosives, and monitoring of the surrounding area, require accurate analyses of field samples. Tests should be conducted rapidly and on site for the most effective remediation to proceed. Recent advances in antibody technology have allowed the introduction of immunoassay techniques to environmental monitoring. Immunoassays now being marketed for environmental analysis, such as products from Ensys and Editek, while extremely selective, have several disadvantages for field use. The Naval Research Laboratory (NRL) has developed a biosensor which can be configured to measure either discrete samples containing explosives, in under one minute, or to monitor process streams at timed intervals. Using a displacement immunoassay, multiple samples can be injected into a micro-column containing a fluorescent signal molecule bound to immobilized antibody. If explosives are present in a sample, the fluorescent molecule is displaced and detected. If the sample contains no explosive molecules, reagents are not expended.

The objective of the present work was to use the existing biosensor for explosives to test soil and water samples from known sites of contamination. Operating parameters for selected molecules, including detection limits, possible interferents in samples, and useful system lifetime are being investigated. Following successful laboratory studies in the initial years of the project, on-site analyses of environmental samples, including soil and groundwater, are currently being performed to detect and quantify the explosives TNT and RDX. A portable device to improve on-site testing is also being developed.

BENEFIT: The primary goal has been to develop a commercial version of the Flow Immunosensor. The Environmental Protection Agency (EPA) has initiated a purchase request for an instrument and will work with NRL to begin the formal methods-validation process, a two-year effort. Their plan is to use the instrument at selected Superfund sites to monitor remediation progress in parallel with the EPA-approved method.

ACCOMPLISHMENTS: During FY97, a portable device to improve on-site testing was developed and work was performed on pre-field trial activities, that included participation of an NRL scientist in a field trial run by the group from U.S. Army Waterways Experiment Station (CU-1043). The field trial was held

at the Louisiana Army Ammunition Depot, and researchers were able to observe their logistical set-up and quality control measures. Work also included the writing of an EPA-format demonstration test plan, with documentation of all standard operating procedures (SOPs) and FAST 2000 instrument protocols. The low-end detection research was also successful, with demonstrated detection limits for TNT and RDX in the low parts per trillion. This level of sensitivity is well below current field methods.

TRANSITION: In coordination with EPA region 10 and the EPA chemists at the Environmental Lab in Manchester, WA, the FAST 2000 portable biosensor was successfully used in a field test. The technology will be transitioned to the industrial contractor, Research International, who collaborated with NRL on this project. It is expected that this work will be continued following transition to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Bioremediation of Fuel and Efficacy Monitoring; CU-30

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Research Laboratory - Washington, D.C.

PRINCIPAL INVESTIGATOR: Dr. Barry Spargo

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective of this project was to develop and transition cost-efficient technologies for in-situ bioremediation and on-line performance monitoring to the end user, through a series of field demonstration programs. The use of conventional chemical and biological assays in combination with the proposed on-line stable isotope analyses developed here, will provide the capability to follow assimilation, respiration, immobilization, transport and biotransformation of pollutants in-situ.

BENEFIT: Stable isotope analysis allows differentiation between degradation products of natural origin and those resulting from degradation of target contaminants. Process performance could be monitored on-line.

ACCOMPLISHMENTS: By monitoring the stable carbon isotope ratio analysis of liberated CO_2, the fate of individual contaminants in a Polycyclic Aromatic Hydrocarbon (PAH)-contaminated site and a Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) spill site were successfully tracked to allow modeling, mass balance determinations, and optimization of Groundwater Circulation Well bioreactors through enhancement with nutrients and electron acceptors.

TRANSITION: The technology will be transitioned to the industrial contractor, SBP Technologies, Inc., who collaborated with the Naval Research Laboratory (NRL) on this project.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ "INSIDE-OUT" NMR Sensor for Contaminant ID; CU-38

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Command Control and Ocean Surveillance Center - San Diego, CA

PRINCIPAL INVESTIGATOR: Dr. Mark North

FY 1997 CANCELLED PROJECT

OBJECTIVE: The objective of this project was to determine the feasibility of adapting the emerging "INSIDE-OUT" Nuclear Magnetic Resonance (NMR) technique of compound identification to rapid site screening of hazardous waste sites. Recent developments in the area of high energy density magnets (rare earth and high temperature superconducting magnets) will allow for a significant reduction in the physical size of this type of sensor. The sensor analyses a well-defined volume of soil surrounding it, without collection of samples, for chlorinated/fluorinated hydrocarbons, fluorocarbons, phosphate based pesticides, explosives and pyrotechnic compounds.

BENEFIT: Fully developed, the NMR sensor was expected to allow for rapid and cost effective screening of proven or suspected sites contaminated with chemical compounds for which it has been calibrated. The ability to identify and quantify contaminants in subterranean strata behind well casings was to allow the placement of a single test well, drilled and cased to the maximum investigative depth, rather than many wells which vary in depth in order to collect the necessary strata effluents.

ACCOMPLISHMENTS: While the initial assessment of feasibility that was completed in FY96 had encouraging results, efforts in FY97 were cancelled. At the annual In Progress Review, the SERDP Office concluded that the expected benefits were not realizable due to the limitations in sensor sensitivity.

TRANSITION: Project cancelled.

PROJECT SUMMARY

PROJECT TITLE & ID: Mobile Underwater Debris Survey System (MUDSS); CU-52

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Surface Warfare Center - Panama City, FL

PRINCIPAL INVESTIGATOR: Mr. Stephen Castelin

FY 1998 FUNDS: $180K

OBJECTIVE: The goal of the MUDSS project is to demonstrate the multi-sensor technologies necessary for underwater surveys of shallow water, both inland and coastal sites littered with unexploded ordnance (UXO). This multi-sensor platform utilizes the following instruments: high-resolution, synthetic aperature sonar; highly-sensitive, superconducting, magnetic gradiometer; electro-optical sensor; chemical sensor; and laser line scanner. A successful demonstration will prove the system concepts for finding and mapping the locations of UXO targets ranging from small shells to large bombs in water depths between four and 100 feet. These technologies can then be applied to the environmental cleanup of underwater UXO targets at scores of formerly used defense sites (FUDS).

BENEFIT: The exact extent and amount of ordnance at most underwater FUD sites is unknown. MUDSS will provide a capability to survey these sites to determine the extent of the problem and also a capability to locate targets for remediation. Each MUDSS sensor will out-perform any commercial off-the-shelf (COTS) sensor, and the integrated MUDSS system will provide performance against UXO targets (including buried ordnance) far exceeding any COTS system. The development cost of this system has been minimized by using hardware and software components from parallel Navy and NASA programs.

TECHNICAL APPROACH AND RISKS: The project has two phases. The first feasibility demonstration phase was completed in FY95. In this phase, existing mine-hunting sonars, magnetic and electro-optic sensors were operated in a very shallow water field having targets of interest. Results showed these sensors had the potential to detect, classify and identify UXO-sized targets. In addition, these data were used to benchmark existing sensor models that will be used to predict performance against other targets and environments. Sensor fusion and display concepts will be developed from the recorded data.

The second phase is the development and demonstration of a field deployable system. This phase will integrate improved sensors with real-time data fusion and displays to aid operators making target detections and classifications. A technology demonstration at a site or sites of interest is planned at the end of Phase II. This phase will take 27 months and start after Phase I.

The technical risks are associated with mine-hunting sensor performance in the very shallow water against small targets. These sensors are usually operated in deeper waters (>30 feet) and against larger sea mine

targets. Phase I testing showed the potential for these sensors to individually detect, classify and identify UXO targets in a very good environment. The environment had targets with minimal corrosion and marine growth, the bottom was sand and had very few other UXO-sized objects (clutter). There is risk associated with the performance in a real FUDS environment where targets might be decomposed and the bottom may have a high amount of clutter. This is were sensor fusion will be evaluated as the method to screen out clutter from targets. Finally, integration of these very sensitive sensors into a field-deployable unit is another inherent technical risk.

ACCOMPLISHMENTS: In FY97, the MUDSS team, with the assistance of the Canadian Fleet Diving Unit Atlantic, collected sediment samples close to UXO targets in Bedford Basin, Halifax, Nova Scotia, for chemical analysis. Trace amounts of explosives were detected from intact UXO that had been submerged for more than fifty years. This showed the feasibility for using chemical sensing to assist in classifying objects that are difficult to identify optically because they are corroded, obscured by marine growth, or buried. The MUDSS project is now preparing for a technology demonstration in FY98 to complete the final year of funding.

TRANSITION: MUDSS is a technology demonstration and transfer program. The research has married developing mine-hunting technologies from the Coastal Systems Station (CSS) with data fusion and visualization technologies developed for National Aeronautics & Space Administration (NASA) by the Jet Propulsion Lab (JPL). Included are plans for an assessment of chemical sensor technology developed by JPL for the Federal Aviation Administration (FAA). The U.S. Army Corp of Engineers (USACE), which has the current mission for munitions remediation and cleanup for over 900 FUD sites, strongly endorsed the transition of MUDSS to an operational capability.

PROJECT SUMMARY

PROJECT TITLE & ID: Joint U.S./Germany In-Situ Bioremediation Demonstration; CU-99

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Maj. Timothy Wiley

FY 1997 COMPLETED PROJECT

OBJECTIVE: The goal of this project was to conduct a field demonstration of bioventing and natural attenuation of a Petroleum, Oil, Lubricants (POL) storage area contamination site at Rhein-Mein Air Base, Germany. The results generated from this field project will assist in successfully transferring these technologies to the German regulatory authorities and the German environmental consulting firms working on U.S. military base clean-up activities in Germany.

BENEFIT: These low-cost technologies are expected to save the U.S. and German governments millions of dollars per contaminated site over conventional cleanup technology. The key outcome of this demo will be performance and cost information to prove to the German attenuation are viable treatment options for hydrocarbon-contaminated aquifer material at U.S. bases in Germany.

ACCOMPLISHMENTS: Field demonstrations of bioventing and natural attenuation were conducted in FY96 so that these strategies will be accepted as proven technologies by German regulatory agencies and may be subsequently implemented to clean up fuel spills at Department of Defense (DoD) installations in Germany. Performance monitoring of the two systems continued in FY97.

TRANSITION: The project's experimental plan has provided enough flexibility to allow for collaborations with a German contractor. The technology that has been gained from the field demonstration will transfer to U.S. Armed Forces Europe Headquarters / Civil Engineer and contractors performing site cleanups at Air Force installations in Europe.

PROJECT SUMMARY

PROJECT TITLE & ID: Permeable Reactive Barriers for In-Situ Treatment of Chlorinated Solvents; CU-107

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: 1Lt Dennis O'Sullivan

FY 1998 FUNDS: $850K

OBJECTIVE: Pump-and-treat technology contains contaminant plumes and removes dissolved-phase contamination in relatively homogeneous geologic formations. As a result of the slight solubility of the contaminant into the surrounding groundwater, and sorption to aquifer materials during transport, pump-and-treat processes require the treatment of massive amounts of water to remove relatively little contamination. Estimates of the duration of pump-and-treat necessary to fully remediate contaminated sites range from decades to centuries. In consequence, the cost of pump-and-treat treatment is extremely high. A newly-developed process, called the funnel-and-gate, is an in-situ technique that directs contaminated groundwater under passive flow through an engineered subsurface region for decontamination.

The main objective of this project is the testing of alternative media at a field-scale, proof-of-principle demonstration. Two or three reactive media will be field-tested to compare their dechlorination potentials. Another objective is to concurrently develop a field-tested permeable barrier design protocol for in-situ remediation of chlorinated solvents in groundwater that would be acceptable to state and Federal regulators.

BENEFIT: Many contaminated sites currently undergoing pump-and-treat remediation are expected to be tractable to funnel-and-gate configurations. With no active pumping involved in the process, these systems may be installed at sites for which power utility installation is a formidable obstacle to installation of pump-and-treat systems. The design protocol will be a tool available for Department of Defense (DoD) restoration project managers to use for designing barriers for other installations/hydrogeologic conditions. This document will also facilitate regulatory acceptance of this technology.

TECHNICAL APPROACH AND RISKS: This project involves the field testing of two or three reactive media in a funnel-and-gate demonstration at Dover Air Force Base (AFB), DE, and may involve innovative emplacement methods to reduce the construction costs of permeable barrier systems. A critical component of the project involves Air Force Research Laboratory/Environmental Quality (AFRL/EQ) and U.S. Environmental Protection Agency (EPA) National Exposure Research Laboratory (NERL) participation in the Remediation Technologies Development Forum (RTDF) Permeable Barriers Working Group (PBWG). This RTDF working group is a consortium of industry, government, and academic partners who share the common goal of developing more effective, less costly permeable barrier treatment technologies.

The design protocol will incorporate results and tools previously developed under this project including the PC-based GROWFLOW groundwater flow model, RACER cost estimating module, and process research for various media. Components of the protocol include: hydraulics modeling; cost estimation; media selection; column studies; longevity studies; emplacement methods; performance monitoring; analytical methods; and data management. Column studies and longevity tests will be performed to evaluate the performance of several candidate reactive media. Results from these studies will be used to determine the most appropriate media to incorporate into the pilot-scale field test.

The four main technical risks associated with this project relate to the performance of the reactive media. First, and foremost, is that long-term performance of reactive media under field conditions is unknown. Therefore, the actual life of the barriers might not match the design life. The second technical risk involves degradation of the reactive media. Previous laboratory column tests indicate precipitation and biofouling might occur in the reactive media. The third technical risk is that incomplete dechlorination might occur within the media. The final technical risk involves the ability of the Lagrangian sampling method to obtain an actual in-field mass balance.

ACCOMPLISHMENTS: A site was selected at Dover AFB to perform a field demonstration in FY 97, which will investigate several reactive media components and innovative emplacement methods for the permeable wall to optimize hydraulic capture and treatment of the plume. In FY97, the site characterization of the proposed analysis area at Dover AFB was completed, with delineation of the outer limits of a shallow Perchloroethylene (PCE) plume and a deep Trichloroethylene (TCE) plume. With contaminant concentrations ranging from 20-5000ppb, with an average of 1000ppb, a groundwater model of the site was constructed and preliminary funnel and gate systems were designed. Design meetings were held with AL/EQ, Dover AFB, Battelle, EPA/NERL, and RTDF members (General Electric, DuPont, University of Waterloo, EnviroMetal Technologies) which led to the completion of the design. With construction and test plans written, submitted to Dover AFB, and accepted, construction bids were solicited and a bidders conference was held at Dover AFB.

TRANSITION: This project will provide a field-tested design guidance to be a tool available for DoD restoration project managers to use for designing barriers for other installations/hydrogeologic conditions. The project researchers presently serve as reviewers for actual and proposed funnel-and-gate pilot demonstrations at a number of sites, including the Environmental Security Technology Certification Program (ESTCP) pilot investigation at Moffett Field, CA, the EPA full-scale demonstration planned for 1998, the Massachusetts Military Reservation (Otis AFB), and other sites. Future plans include working with Navy design teams and the Army Corps of Engineers to apply the technology as widely as possible.

PROJECT SUMMARY

PROJECT TITLE & ID: Trichloroethylene Risk Assessment; CU-115

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Wright Patterson Air Force Base, OH

PRINCIPAL INVESTIGATOR: Dr. Jeffrey W. Fisher

FY 1997 COMPLETED PROJECT

OBJECTIVE: The goal of this research was to present the U.S. Environmental Protection Agency (EPA) with an alternative Trichloroethylene (TCE) risk assessment which replaces non-scientific policy assumptions with science-based evaluation.

TCE is among the top-ten priority groundwater contaminants within the Department of Defense (DoD) and nationally, and is present at over 39 percent of Superfund sites. The current required cleanup level in groundwater is low (5 ppb), with compliance costs estimated at billions of dollars. A typical stripping tower operation costs over a million dollars annually to operate, with an expected 15-20 year duration. Required cleanup levels are based on a risk assessment paradigm that includes significant policy-driven assumptions and safety factors. This leads to substantial uncertainty regarding the correlation between the cleanup level and cost-effective protection of human health.

Currently, all carcinogens are evaluated by the U.S. EPA on the basis of assumptions made for mutagenic chemicals but scientific opinion places TCE in a different class of carcinogens: promoters. However, draft revised U.S. EPA Guidelines for Cancer Risk Assessment are based on the premise that each chemical should be evaluated based on the "weight of evidence rather than using a standard approach to all chemicals." They state that "assumptions are to be displaced by facts or better reasoning when appropriate data are available." This project greatly broadens the TCE research data base and incorporate innovative, probabilistic risk assessment approaches. Reevaluation of TCE based on its activity as a promoter, not a mutagen, can reasonably be assumed to result in a remediation level significantly greater than 5 ppb.

BENEFIT: Because the current remediation level (5 ppb) is extremely difficult to achieve, remediation costs are very sensitive to even small changes in this level. Revised TCE remediation goals, which are the likely result of an updated EPA risk assessment, will have a major impact on TCE remediation costs. New remediation goals will make this a dual-use technology with extensive application in the civilian sector.

ACCOMPLISHMENTS: In FY 1997, efforts included the investigation of the reported increase (7-9 percent) in heart malformations of developing rodent fetuses from maternal ingestion of low concentrations of TCE in water. This is the most sensitive non-cancer effect reported for TCE. A cardiac malformation study is near completion to validate or refute previous research findings. Also, work included the

finalization of the physiologically-based pharmacokinetic (PBPK) models for rodents and humans for use in dose response assessment.

TRANSITION: The PBPK models for rodents and humans were transferred to the U.S. EPA this year for use in dose response assessment, and three chapters were written supporting the state-of-the-science portion of the new trichloroethylene health assessment document that is under preparation by the U.S. EPA. A draft report of the new trichloroethylene health assessment is expected to be available for public comment in CY 1998.

PROJECT SUMMARY

PROJECT TITLE & ID: Bioremediation of Hydrazine; CU-118

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Mr. Jim Hurley

FY 1997 COMPLETED PROJECT

OBJECTIVE: Numerous industries use hydrazine fuels on a daily basis. The U.S. Air Force (USAF) and National Aeronautics and Space Administration (NASA) utilize the fuels as a high energy missile and rocket propellant. However, hydrazine usage is not isolated to the Department of Defense (DoD) and NASA. Numerous civilian companies use hydrazine in boiler rooms as a corrosion inhibitor, in the manufacture of agricultural chemicals, and in the development of pharmaceuticals. The primary objective of this project was to discover, develop, and optimize a cost-effective environmentally conscious, and biologically mediated process for the remediation of hydrazine disposal and spill response techniques/options.

BENEFIT: As a result of this research and development endeavor, a biologically mediated process for the in-situ remediation of hydrazine contamination will be developed. The technique will fully satisfy the USAF's need for a cost-effective and environmentally sound hydrazine degradation process. The remediation technique can potentially be applied to the remediation of other environmental contaminants.

ACCOMPLISHMENTS: The biocatalyst, diazoluminomelanin (DALM), has been selected for the remediation of hydrazine. DALM is a synthetic melanin, humic substance isolated from bacterial cell walls. The material, which is resistant to breakdown, is a free radical generator. The free radicals will be utilized in the destruction of residual hydrazine following a hydrazine spill. Toxicology and transport studies were completed in FY97 to ensure that degradation products are not harmful to the environment and to determine on a risk basis the effective range of biocatalyst that can be used during cleanup.

TRANSITION: The patent application covering the genetically engineered bacterium that produces the catalyst was filed in August 1997. The biocatalyst is now being supplied to Foster-Miller, Inc., that is developing a supersorbent gel containing the catalyst in order to take up spilled hydrazine so that it may be broken down by the contained catalyst. Foster-Miller is now in a Phase II Small Business Innovation Research (SBIR) that should have a field demonstration of the technology in the summer of 1998.

PROJECT SUMMARY

PROJECT TITLE & ID: Aquifer Restoration by Enhanced Source Removal; CU-368

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Environmental Protection Agency

LAB: National Risk Management Research Lab - Ada, OK

PRINCIPAL INVESTIGATOR: Dr. Carl Enfield

FY 1998 FUNDS: $2,180K

OBJECTIVE: Low-solubility organics such as chlorinated solvents were used and released to the environment in massive quantities during the 1950s, '60s, and '70s. These contaminants have migrated through the subsurface and entered groundwater at more than 1,000 Department of Defense (DoD) sites. At these sites, the organic contaminants are found in one of four phases: (1) volatilized within the soil's vadose zone (vapor phase), (2) dissolved in the groundwater (dissolved phase), (3) sorbed to the aquifer solids (sorbed phase), or (4) as a separate non-aqueous phase liquid (NAPL) phase. All of these contribute to the contamination and need to be removed.

The limiting factor to satisfactory remediation at over 75 percent of the hazardous waste sites in the United States is restoration of groundwater quality. The major limitations to the successful use of pump-and-treat technology are related to difficulties in extracting contaminants from source areas where NAPLs exist. The objective of this research is to take extraction (solubilization and mobilization) science, which has been developed at bench scale, and evaluate its potential for enhancing extraction in the source area. Design manuals are to be developed and evaluated using field pilot-scale cells comparing technologies side-by-side.

BENEFIT: It is estimated that over 90 percent of the contaminants in the subsurface environment is contained in the source area. Until the source area is remediated or contained, it will not be possible to obtain a permanent closure for any of the sites. Pump-and-treat systems are the primary technology in use at sites with contaminated groundwater. Because of their inability to effectively clean source regions of contaminated waste sites, many of them will be operated "in perpetuity." The cost of operating and maintaining these systems is enormous, and the institutional arrangements to keep them operating for tens to hundreds of years do not exist. Bench-scale studies suggest that it will be possible to remove the majority of the NAPL where the source can be identified. The time required for this removal is small compared to the time required if pump-and-treat technologies are used. Estimated costs for groundwater remediation by DoD and other Federal agencies range upward of hundreds of billions of dollars, and even incremental improvements in efficiency will justify the cost of the proposed research.

TECHNICAL APPROACH AND RISKS: The proposed work will be a series of field demonstrations of enhanced pump-and-treat technologies supported by site characterization and laboratory research required to produce credible field demonstrations and evaluations. The work will focus on remediation

of source areas of sites believed to be contaminated by NAPLs at residual concentration (no longer mobile and, therefore, not available for extraction by pumping).

The processes will be demonstrated at different sites with different hydrogeology and different chemical mixtures (both NAPLs and sorbed contaminants will be considered) to determine their performance under a variety of conditions. The tests will be conducted as controlled, small-scale field projects. Each technology will be compared with one or more alternative remediation technologies including conventional pump-and-treat as a reference treatment system. The results of these comparisons will show the differential improvement achieved by one process relative to another. Success of the project will be dependent on: the ability to obtain access to actual sites; obtaining regulatory permission to perform non-standard, pilot-scale evaluations without significant delay; and maintaining continuity of funding throughout the project.

ACCOMPLISHMENTS: In FY97, installation of test cells was initiated at the test cell at the Ground Water Remediation Field Laboratory, Dover Air Force Base (AFB) Delaware. Both test cells have been installed, and shown to not be leaking at any significant rate, and all of the injection and extraction wells have been installed using direct-push techniques and have been developed by the Environmental Protection Agency (EPA). Also, a semi-automated sampling system has been installed and tested in test cell number 2. An environmental protection strategy and release strategy have been developed and submitted to the regulators for approval. A meeting was held with Delaware Department of Natural Resources and Environmental Control (DENREC), EPA Region 3 and Air Force personnel to address concerns with the permit application, however, additional work cannot be conducted until a permit is approved.

TRANSITION: The results of these comparisons between alternative remediation technologies will be compiled in a manual. This manual will be prepared for the user community to permit design of these systems. The design manual will contain anticipated system performance and will be made widely available to facilitate transition of the technology developed.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program — Consortium for Site Characterization Technology; CU-374

RESEARCH CATEGORY: 6.4 Demonstration and Validation

LEAD AGENCY: U.S. Environmental Protection Agency

LAB: National Exposure Research Laboratory - Las Vegas, NV

PRINCIPAL INVESTIGATOR: Mr. Eric Koglin

FY 1998 FUNDS: $60K

OBJECTIVE: The goal of this National Exposure Research Laboratory (NERL) effort is to evaluate, and report on innovative and alternative monitoring, measurement and site characterization technologies in support of the Department of Defense (DoD) National Environmental Technology Test Sites (NETTS) program. This will facilitate the acceptance and use of cost-effective technologies applicable to a wide range of environmental problems, particularly focusing on hazardous waste site assessment, characterization, and monitoring. There is a clear need to ensure that better, faster, and less expensive technologies are available for cleaning up Installation Restoration Program (IRP) and Base Realignment and Closure (BRAC) sites. Achieving cost-effective site cleanup is in everyone's best interest. However, currently there is a long lag time between the successful field demonstration of a new technology and its routine use. This will likely continue unless a concerted effort is made to advance innovative and emerging technologies. It is also apparent that without active involvement by the Environmental Protection Agency (EPA), the emergence and use of new technologies will continue only slowly. An objective of this demonstration program is to facilitate acceptance by regulators and to develop a data base of information relating to these new technologies.

BENEFIT: Savings in site cleanup will reduce the need for new or additional Federal taxes to support federally funded cleanups. Lower costs for cleanups funded by private parties should reduce inflationary pressures. The NETTS demonstration program will provide a central conduit to channel new technologies to the marketplace more expediently than current methods. Investment capital should be easier to obtain because the developer will have a technology acceptance road map to show to investors. The focus of this project is to support the use and implementation of new technologies by rapidly introducing them to the user community through training, field trial, and direct application at current sites. This demonstration activity is designed to: maximize information transfer and reduce duplication; provide assistance to public and private sector users and developers; support the diffusion of technologies derived from basic and applied Research and Development (R&D) programs; and be a collaborative effort.

TECHNICAL APPROACH AND RISKS: NERL supports the DoD NETTS program by providing planning support for the demonstration of site characterization technologies developed by SERDP or other technology development sponsors (where the technology can be used to support a DoD requirement).

NERL is also responsible for producing guidance on how to conduct and evaluate these types of technologies; providing support to the other National Test Locations Managers in conducting demonstrations; and for managing and disseminating information on demonstrated technologies.

ACCOMPLISHMENTS: In FY97, this project continued to sustain the EPA-led portion of the NETTS for facilitating the development, commercialization, and use of innovative monitoring, measurement, and site characterization technologies. NERL has supported the planning and administering of demonstrations of SERDP-developed technologies for site characterization and monitoring technology, as well as technologies funded by other sources. NERL has also continued to produce guidance on how to conduct and evaluate these types of technologies, and for managing and disseminating information on demonstrated technologies.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: Enhancing Bioremediation Processes in Cold Regions; CU-712

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Army

LAB: Cold Regions Research and Engineering Laboratory - Hanover, VT

PRINCIPAL INVESTIGATOR: Dr. Charles M. Reynolds

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective of this project was to develop rhizosphere-based remediation systems to improve bioremediation ability in areas subject to low temperatures. The quantity of soil that requires treatment necessitates using techniques that expose soil to seasonal temperature cycles and extended periods of freezing. The net influence of freezing temperatures on the overall rate and extent of soil biotreatment is not sufficiently known to exploit or manage biotreatment systems in advantageous ways. Enhanced microbial activity in rhizosphere zones is documented for some pesticides. The effort utilized a sampling method developed to address the primary technical risks: the difficulties in getting sufficiently precise data to show treatment effects and in evaluating nutrient competition between the selected plant and soil microbial populations.

BENEFIT: The benefit is savings in cost, time, and liability. Savings are site specific and largely a function of available alternatives, but costs using rhizosphere-enhanced remediation are conservatively estimated to be one-tenth that of currently available alternatives. Results from conducting monitored, documented, and defensible demonstrations of rhizosphere-enhanced biotreatment options could be readily field implemented where appropriate. These low-cost alternatives would be applicable in both northern and temperate regions. Additionally, the methodology and lessons learned will be useful as we extend this type of treatment to other compounds.

ACCOMPLISHMENTS: In FY97, results have documented enhanced populations of contaminant degrading microorganisms and greater degradation in rhizosphere soil in laboratory studies. Research efforts have extended these results to a field research site in Alaska. This may offer a significant mechanism for low-cost soil treatment. We have shown that limitations to bioremediation at remote sites can be overcome by stimulating soil-rhizosphere effects and will be further quantifying and demonstrating this process.

TRANSITION: This effort will transition through: 1) the Environmental Security Technology Certification Program (ESTCP) project, Field Demonstration of Rhizosphere-Enhanced Treatment of Organics-Contaminated Soils on Native American Lands with Application to Northern formerly used defense (FUD) Sites; 2) ongoing reimbursable field projects; and, 3) applied research work units in the Army Environmental Quality Technology Program.

PROJECT SUMMARY

PROJECT TITLE & ID: Explosives Conjugation Products in Remediation Matrices; CU-715

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Judith Pennington

FY 1998 FUNDS: $500K

OBJECTIVE: During investigations of potential treatment technologies for explosives-contaminated soils, specifically during bioslurry treatability studies and composting, TNT has been observed to interact with some component of the treatment matrix in such a way as to preclude extraction with organic solvents. Similar interactions have been observed in explosives-amended soils: mass balance determinations using radio-labeled TNT reveal that the radioactivity is still present in the matrix in some unknown form. As much as 80 percent of the radioactivity added to tests is accounted for in the unextractable matrix. Therefore, the parent compound has not been completely destroyed, but has changed to a more complex form. The long-term stability and environmental safety of these uncharacterized conjugates are unknown. Objectives of this basic research include characterization of these explosives conjugates, development of an analytical methods for identifying them in treatment systems and in soils, and determining the long-term stability and environmental safety of the conjugates. Accomplishment of these objectives will ensure the development of effective remediation technologies that ameliorate environmental health effects and lead to a more complete characterization of the end products of new treatment technologies. Research was initiated to determine the basic mechanisms of interactions between TNT and humus, soil enzymes and clays under SERDP in FY93. This proposed research intends to expand upon that effort.

BENEFIT: The Department of Defense (DoD) places a high priority on development of truly effective remediation technologies for explosives-contaminated soils and groundwater. Nevertheless, most current technologies fail to demonstrate complete destruction of explosives. Rather, explosives are transformed to related conjugation products that are recalcitrant to further characterization. Although these products are suspected of being relatively unavailable for transport or toxicity in the short term (weeks to months), their ultimate fate in the long term (years) is unknown. This lack of understanding of the ultimate fate of explosives severely limits the credibility of certain remediation technologies. This study will improve existing and future remediation technologies by identifying the types of chemical bonding and potential environmental impacts of explosives conjugates in remediation matrices.

TECHNICAL APPROACH AND RISKS: The ability of explosives to form conjugates with soil organic fractions (i.e., humic acids, fulvic acids, and enzymes such as peroxidase, laccase, and tyrosinase), clays (i.e., montmorillonites and kaolinites), and other mineral components of remediation matrices (i.e., oxy/hydroxy compounds of iron and other minerals) will be evaluated. The influence of environmental

factors such as temperature, pH and moisture regimes on development and characteristics of conjugates will also be determined. Classical extraction and analytical techniques have been ineffective in removing and describing these unextractable conjugates. Therefore, innovative analytical techniques will be applied. The role of microbial processes in conjugation of explosives to microbial cell walls will be investigated. Factors affecting stability of the conjugates to leaching and microbial degradation will be determined. Characterization of the ecotoxicology of conjugates will answer the question of whether conjugates are environmentally compatible. The potential for reappearance of toxicity from re-release of parent compound or from the formation of toxic metabolites will be investigated. Microbial mutagenic and cultured cell line in vitro assays, and whole organism adult and early life-stage bioassays will be used. The influence of environmental factors on bioavailability and on the time course of toxic potency will be determined. Compost material from a DoD National Environmental Technology Test Sites (NETTS) program site will be tested if available.

ACCOMPLISHMENTS: Progress continued on this study to characterize these conjugates, develop analytical methods for their identification, and determine their stability and environmental safety. Efforts in FY97 included the development of hydrolytic methods for releasing identifiable explosives-related products from conjugated matrices, identification of conjugates by covalent linkage with humic acid functional groups using nuclear magnetic resonance, microbial degradability of conjugated products, and toxicology of explosives transformation and conjugation products. Results to date indicate that conjugates result from several processes occurring in the matrix. And results of earthworm bioassays revealed that TNT in the matrix invoked an avoidance response in the worms, altered some enzyme activities, and compromised the immunocompetence of the worms.

TRANSITION: This project will transition widely to DoD sites contaminated with explosives. Acceptance of remediation technologies will be enhanced with regulatory agencies and other users concerned with the ultimate safety and environmental effects of explosives. Furthermore, an understanding of the nature and properties of conjugation products will lead to new and improved approaches to remediation.

PROJECT SUMMARY

PROJECT TITLE & ID: Federal Integrated Biotreatment Research Consortium: Flask to Field Initiative; CU-720

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Mr. Jeffrey W. Talley

FY 1998 FUNDS: $2,600K

OBJECTIVE: The objective of this project is to develop a set of "realistic" biotreatment processes for cleanup of several classes of contaminants at Department of Defense (DoD) sites. A single, panacea technology for each contaminant group that can be used at all DoD sites will not be obtained. All treatment processes have technical and economic limitations, and part of the experimental process of this program will be to define these limitations.

BENEFIT: The primary benefit of this study is reduced remediation costs associated with development of "realistic" biotreatment processes for cleanup of contaminated DoD sites. Secondary benefits include: expanded implementation potential of existing and developing biotreatment processes, biotreatment technologies that result in the on-site destruction of contaminants, and increased regulatory and user acceptance.

TECHNICAL APPROACH AND RISKS: The technical approach will be to continue to investigate a variety of promising biotreatment processes at the bench and intermediate scale. The experiments in this program will be directed toward four major research areas. These areas are biological treatment of explosives, chlorinated solvents, polychlorinated biphenyls (PCB), and polycyclic aromatic hydrocarbons (PAH). The experiments planned for these efforts represent up-to-date techniques that indicate promise for reducing treatment costs at DoD sites. In some cases, the concepts under investigation have been developed by members of this consortium. In other cases, other concepts that indicate promise were taken from current literature and professional affiliation. Considerable efforts have been made and will continue to be made to ensure that our approach is always up-to-date. Our technical approach and processes under development do have potential for being fielded within a reasonable amount of time. This approach will ensure that the DoD will have more cost-effective remediation technology at its disposal within a time frame that DoD can utilize them during its efforts at site remediation.

As mentioned above, the following describes the four major contaminant groups:

THRUST AREA: EXPLOSIVES CONTAMINATED SOILS AND GROUNDWATERS

A variety of promising biotreatment techniques will be investigated for remediation of soil and groundwater contaminated with explosives compounds. Explosives contamination represents one of the most prevalent types of organic contamination within the DoD. The following biotreatment mechanisms will be investigated for explosives:

a. Discovery of Novel Enzymatic Reactions and Determination of Biodegradation Mechanisms and Pathways.
b. Phytoremediation of Explosives Contaminated Groundwater using Wetlands and Aquatic Plants.
c. Phytoremediation of Munitions Contaminated Soils.
d. Enhanced TNT Biodegradation Through Genetic Manipulation.

THRUST AREA: PAH CONTAMINATED SOILS

This group of contaminants represents the most regulated of PAH compounds due to their carcinogenic properties. Also, because of their large and complex molecular structure, they also represent the most difficult of all the PAHs to biologically degrade. Key research issues are:

a. Heavy Molecular Weight PAH Biodegradation.
b. Mass Transfer and Bioavailability Enhancement for In-Situ Intermittent Slurry Reactor Treatment of Dense Non-Aqueous Phase Liquid (DNAPL)-Contaminated Soils.

THRUST AREA: CHLORINATED SOLVENT CONTAMINATED SOILS AND GROUNDWATERS

Chlorinated solvents represent a class of contaminants that is detected at more DoD sites [and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) sites for that matter] than any other contaminant group. Issues under investigation for chlorinated solvents within this program include:

a. Electrically Activated Reductive Dechlorination of Chlorinated Solvents
b. Distinguishing the Microbial Communities Active in the Enhanced Aerobic Treatment of Chlorinated Ethenes.
c. Phytoremediation of Shallow Chlorinated Solvent Plumes: Engineered Tree Planation and Transgenic Trees to Secrete Dehalogense Enzymes.

THRUST AREA: PCB CONTAMINATED SOILS

Soils contaminated with PCBs represent one of the most challenging compound groups under investigation in this project. PCBs are found at many DoD installations due to improper disposal of hydraulic fluids and waste lubricating oils. Primary issues under investigation are: Enhancing PCB Biodegradation.

ACCOMPLISHMENTS: In FY97, the Consortium has continued to support engineering groups working closely with scientists in understanding the mechanisms and pathways of biodegradation, in evaluating the potential of the resulting technologies, and in the transfer of technologies from bench-scale to field. In FY97, this relationship has resulted in field testing of a fluidized-bed technology for biodegradation of mixtures of 2,4- and 2,6-dinitrotoluenes in contaminated groundwater. This operational startup of

Fluidized Bed Reactor (FBR) Pilot Demonstration at the Volunteer Army Ammunition Plant (VAAP) was based on recommendations from and coordinated by SERDP. Since explosives contamination represents one of the most prevalent types of organic contamination within DoD, a variety of innovative and promising biotreatment techniques with potential high payoff have been investigated in FY97 and will continue to be investigated for the remediation of soil and groundwater. For the trinitrotoluene (TNT) research effort, Patent Application has been filed for "Mechanism for Phytodegradiation of Munitions". Method and Composition Patent was awarded in 1997. For enhanced biodegradation of TNT, genetic modification technique has been employed to better understand how the environment controls the evolution of new genetic capabilities in microorganisms as well as the mechanisms of regulating the expression of these genes. Isolation of the 16S rRNA gene was successfully completed.

Other FY97 efforts were focused to achieve in-situ intermittent slurry biotreatment of PAHs, the development, construction, assessment, and execution of preliminary mass transfer and biodegradation experiments using intermittently mixed slurry reactor has been completed. Under the PCB biodegradation research effort, catabolic capability of four target strains was characterized based on the range of PCB cogener attack, their tolerance to high PCB concentrations, their growth rates and yield on biphenyl, and gram positive and gram negative cell walls. Also, the scheme for transferring and expressing dehalogenase genes was successfully implemented.

TRANSITION: This project has a transition plan that intends to offer the DoD community a biotreatment "toolbox" that can be drawn upon to offer the right process for each site. The technology produced by this project is intended to serve remediation project managers want options and well defined limitations of each option made available to them during their remediation efforts. Each process, whether it is traditional or innovative, has technical limitations and risks associated with its fielding, and the knowledge of process shortcomings is required to reduce the risk accepted by the installation and regulatory agencies to an acceptable level.

PROJECT SUMMARY

PROJECT TITLE & ID: Accelerated Tri-Services SCAPS Sensor Development; CU-729

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Ernesto R. Cespedes

FY 1998 FUNDS: $500K

OBJECTIVE: The objective of this project is to accelerate the development, testing, and demonstration of new or enhanced sensor technologies for detecting and delineating subsurface contaminants in-situ. This work will significantly expand the capability of the Site Characterization and Analysis Penetrometer System (SCAPS) to detect chemical contamination in soils and groundwater. Additionally, this project includes development of improved sampling, analysis, and data processing technologies to support the new or enhanced sensor technologies.

BENEFIT: This work will provide the Department of Defense (DoD) and Department of Energy (DOE) with an expanded capability to conduct site characterization and monitoring using SCAPS. Successful development and fielding of advanced SCAPS sensors will significantly accelerate site characterization efforts and will reduce costs. Immediate payoff will be technology for volatile organic compounds (VOCs), explosives, and heavy metal contaminant detection, and improved Petroleum, Oil, Lubricants (POL) detection. Improved SCAPS sampling technology will provide alternative cost-effective methods to obtain site characterization and verification data. Hybrid sampling technologies coupled to sensors and in-situ methods for contaminant extraction will greatly expand the utility of SCAPS technology. The Tri-Service SCAPS will serve as a test platform for all technology development and will accelerate the evaluation of effectiveness and feasibility for subsequent demonstration activities. Rapid development and fielding of sensor technologies for SCAPS will significantly increase its return on investment.

TECHNICAL APPROACH AND RISKS: Initially, identification and evaluation of candidate sensing technologies which address DoD, DOE, and Environmental Protection Agency (EPA) contaminants of interest and which have potential for rapid in-situ SCAPS applications will be conducted. Laboratory instrumentation will be developed to determine limits of detection, define soil matrix effects, and evaluate SCAPS implementation considerations. Associated support technologies, including data acquisition, analysis, and visualization systems will be developed and tested. Prototype SCAPS sensor and sampler probes will be developed and tested in controlled laboratory and field experiments. SCAPS field tests and demonstrations will be conducted to validate SCAPS technologies and to increase acceptance by regulators, users, and the public. These field tests will make maximum use of available DoD National Environmental Technology Test Sites (NETTS) program test sites. Technical risks associated with this project include uncertainties involved in transitioning laboratory methods to field-use technology, and the ability to control

the variabilities of sensor performance that result from site-specific conditions such as variations in soil stratigraphy, interference sources, presence of multiple contaminants, and changes in contaminant state.

ACCOMPLISHMENTS: In FY97, SCAPS researchers completed SERDP-funded laboratory and field evaluations of SCAPS samplers [transitioned to Environmental Security Technology Certification Program (ESTCP) for validation and certification]. Activities included the initial field tests of Laser-induced Fluorescence (LIF) probe that incorporates the Massachusetts Institute of Technology/Lincoln Laboratory microchip laser, as well as the design, development, and fabrication of an improved fiber optic Laser-induced Breakdown Spectroscopy (LIBS) probe (Patent application filed - Navy Case No. 78165). Also completed were improvements to the X-ray fluorescence (XRF) probe, and successful field tests of the XRF and electrochemical sensors at Joliet Army Ammunition Plant, IL. All these probes successfully detected subsurface lead contamination, and these technologies are being transitioned to ESTCP for dem/val testing during FY98. Other activities included completion of: 1) design of SCAPS Surface Enhanced Raman Sensor (SERS) probe; 2) fabrication and laboratory testing of SERS probe; and 3) successful initial field test of "cone sipper" probe for the SERS probe at Naval Air Station North Island, CA. Successful field demonstrations of an electrochemical VOC sensor, a multiport sampler, and a VOC thermal desorption sampler were also conducted.

TRANSITION: Technology developed under this proposed effort will be transitioned to the U.S. Army Environmental Center (AEC) which is the agency responsible for demonstrating and transitioning SCAPS technologies to the U.S. Army Corps of Engineers District Offices, the Naval Facilities Engineering Command, the Air Force System Program Office, and also to DOE-Headquarters. Transition of SCAPS technology to private industry will be pursued by licensing agreements for patented technology and through Cooperative Research and Development Agreements (CRADA).

PROJECT SUMMARY

PROJECT TITLE & ID: Environmental Risk Assessment Program; CU-770

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Environmental Protection Agency

LAB: Environmental Criteria & Assessment Office - Cincinnati, OH

PRINCIPAL INVESTIGATOR: Dr. Terry Harvey

FY 1997 COMPLETED PROJECT

OBJECTIVE: The goal of the Environmental Risk Assessment Program (ERAP) has been the improvement of scientific methods and models for the performance and application of risk assessments for human and ecological issues. As such, the program has involved joint scientific reviews, with consensus deliberations, of pollutants of mutual concern to the Department of Defense (DoD), Department of Energy (DOE), and Environmental Protection Agency (EPA), and the development of new and improved human health, exposure and ecological methodologies for assessing risks related to federal facilities. The program has strived to identify and evaluate existing risk assessment processes, data gaps and weaknesses in current methodologies; to explore, develop and validate alternative risk and exposure assessment methods and models for application at DoD and DOE facilities; and to share new risk assessment methods and models across Federal agencies and the scientific community.

BENEFIT: The program will provide consensus toxicity values for assessing human health and ecological risks(s) pertaining to materials and chemicals found at Federal facilities. The program will also make available the most appropriate scientifically based methodologies for consistent application to these risk assessments.

ACCOMPLISHMENT: The work exemplifies the potential for greatly reduced remediation costs. Acute, subacute, subchronic, chronic, toxicokinetic, reproductive, and developmental studies conducted by the U.S. Army and the U.S. EPA provided the scientific database to develop a 600-fold higher Reference Dose (RfD) of 0.03 mg/kg/day for 1,3,5-trinitrobenzene (TNB) based on toxic effects (hematopoietic effects) common to other nitroaromatics. The new RfD has undergone external peer review and is in final adoption stage by the inter-agency Advisory and Coordinating Committee. In addition, a new standard for TNB was successfully included in August 1997 in the U.S. EPA Integrated Risk Information System (IRIS), and was assigned CAS No. 99-35-4.

TRANSITION: Plans include the transfer of ERAP products to local risk assessors and risk managers.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program — McClellan AFB, CA; CU-861

RESEARCH CATEGORY: 6.4 Demonstration and Validation

LEAD AGENCY: U.S. Air Force

LAB: McClellan Air Force Base - Sacramento, CA

PRINCIPAL INVESTIGATOR: Mr. Phil Mook

FY 1998 FUNDS: $130K

OBJECTIVE: The National Environmental Technology Test Site (NETTS) program goal is to enable efficient demonstration of candidate detection, monitoring or cleanup technologies, either on an individual basis or in parallel with similar projects, under representative hydrological and climate regimes as found at many contaminated sites in the Department of Defense (DoD). Current environmental cleanup technologies are costly, slow, and largely ineffective. The program will provide test beds for research to fully understand the mechanisms in proposed treatment processes. The NETTS National Test Location at McClellan Air Force Base (AFB) provides test sites to investigate technologies for treatment of unsaturated soils and extracted soil-gas contaminated with chlorinated solvents, as well as ex-situ treatment of contaminated groundwater. As part of its cleanup effort, McClellan AFB has been well characterized.

BENEFIT: Test locations are fully characterized and monitored areas where new technologies can be quickly and effectively demonstrated. This will save time and money for technology demonstrations by providing on-site management, pre-characterization, and more timely permitting. An established, dedicated test site will enable technology demonstrations to be performed at a cost lower than that of a one-time demonstration elsewhere.

TECHNICAL APPROACH AND RISKS: As a NETTS test location, McClellan AFB provides a well-characterized demonstration site for applied research, demonstration, and evaluation of promising cleanup and monitoring technologies. McClellan AFB currently has four operational and two planned Soil Vapor Extraction (SVE) Systems. All systems have dedicated utilities, adjacent to it allowing for convenient slip-stream demonstrations. McClellan AFB's groundwater treatment plant currently services 23 extraction wells. The SVE systems and groundwater treatment facility provide opportunities for demonstrating in-situ and ex-situ techniques for remediating soils and groundwater contaminated with solvents. There are more than 375 groundwater monitoring wells located on and around McClellan AFB.

ACCOMPLISHMENTS: The McClellan NETTS test location successfully provided the capability for treatment of unsaturated soils and extracted soil-gas contaminated with chlorinated solvents, as well as ex-situ treatment of contaminated groundwater. In FY97, the McClellan NETTS test location successfully

completed five demonstrations and provided field support for six ongoing demonstrations that will continue their efforts into FY98.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program — Naval Construction Battalion Center (CBC), Port Hueneme, CA; CU-863

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Facilities Engineering Service Center - Port Hueneme, CA

PRINCIPAL INVESTIGATOR: Mr. Ernest Lory

FY 1998 FUNDS: $700K

OBJECTIVE: The objective of the Navy Construction Battalion Center (CBC) National Environmental Technology Test Sites (NETTS) National Test Location (NTL) at Port Hueneme, CA, is to support demonstration of systems for characterizing and remediating soil, sediments, and groundwater contaminated with fuel hydrocarbons and/or waste oil. It provides test sites to investigate both ex-situ technologies for treatment of soils and in-situ technologies for groundwater contaminated with fuel hydrocarbons.

BENEFIT: The NTL for fuel hydrocarbon and waste oil provides well characterized test locations, controlled field conditions for comparative evaluations of technologies, uniform evaluation criteria for demonstrations, reporting of results and technology transfer, and cost savings through amortization of infrastructure and management.

TECHNICAL APPROACH AND RISKS: The Test Location Manager (TLM) at CBC, Port Hueneme will provide programmatic, infrastructure and technical support to NETTS for fuel hydrocarbon and waste oil characterization and remediation demonstrations. Programmatic support will include integration of the following: (1) Quality Assurance/Quality Control (QA/QC) procedures, (2) test protocol guidance, (3) demonstration reporting format, and (4) environmental setting, cost-and-performance data retrieval guidance. Infrastructure and its management (operation and maintenance) will include: (1) monitoring wells, (2) in-line sensor network, (3) ex-situ treatment facility with hazardous material handling capability, (4) utilities, (5) contaminated soil, sediments and groundwater resources. Technical support will include: (1) characterizing and monitoring contaminants, (2) processing permits, (3) supporting stakeholder involvement, and (4) transferring technologies.

ACCOMPLISHMENTS: The Port Hueneme NETTS test location provided: (1) management support for SERDP projects including installation of utility service, (2) support for the Oxnard Plain Military Community Public relations process, (3) operation and maintenance of ex- and in-situ demonstration sites, (4) completion of regulatory required monitoring for air and water permits, (5) attendance at meeting of D/NETTS managers to discuss operational issues and concerns, and (6) guidance to Principal Investigators

(PIs) on preparing Application Analysis Report following instructions found in the Guidelines for Quality Technology Demonstrations.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program — former Wurtsmith AFB, MI; CU-864

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Environmental Protection Agency

LAB: University of Michigan, National Center for Integrated Bioremediation Research & Development - Oscoda, MI

PRINCIPAL INVESTIGATOR: Dr. Michael Barcelona

FY 1998 FUNDS: $500K

OBJECTIVE: The objective is to operate and maintain a National Environmental Technology Test Sites (NETTS) National Test Location at the National Center for Integrated Bioremediation Research and Development (NCIBRD) which investigates advanced technologies in site characterization, decontamination of hazardous wastes, and remediation of spill and disposal sites. Under NETTS, well-characterized test sites will be provided for technologies with evident promise for complete and cost-effective remediation with minimal environmental disruption, which are favored for facility usage. These technologies involve on-site and in-situ processes which integrate biological and physicochemical methods for treatment of soils and groundwater contaminated with fuels, chlorinated solvents, and organic mixtures. NCIBRD is located at the recently decommissioned Wurtsmith Air Force Base (AFB) in Oscoda, Michigan, which has numerous fuel and chlorinated solvent contamination sites resulting from former Air Force activities.

BENEFIT: This test location provides significant direct and indirect benefit to the Department of Defense (DoD), Department of Energy (DOE), and Environmental Protection Agency (EPA) environmental Research and Development (R&D) programs by enabling advanced site characterization and remediation technologies to be evaluated on a common baseline. It also provides a standardized testing procedures and cost-and-performance evaluation guidelines which should expedite the approval process for new technologies and in turn facilitate the transfer of those technologies from the development stage to operational use. Field-scale testing at sites which are well characterized and monitored on a continuing basis will save considerable amounts of money in evaluating individual technologies for DoD use.

TECHNICAL APPROACH AND RISKS: Activities at NCIBRD include an array of research, development, demonstration, testing and evaluation efforts toward the transfer of field and laboratory findings into successful remediation practice. The program focuses on several specific problems relating to the development of core biotechnologies such as the enhanced understanding of microbiology and microbial geochemistry, improved means for implementing biotechnology in engineering applications, and accelerated bioremediation of contaminated soils and groundwater. Controlled programs on site characterization and in-situ integrated remediation technologies for decontamination of hazardous substances in wastes, soils, and groundwater are conducted at the facility. The majority of the sites at the

base have been characterized to some extent. Several of the larger sites are under hydraulic control by way of pump-and-treat systems. A subset of three fuel and chlorinated solvent sites have been characterized geochemically and microbially in support of in-situ bioremediation. The facilities provide a focal point for coordination and cooperation within the broad community of institutions, agencies, and corporations currently attempting to develop these technologies.

ACCOMPLISHMENTS: The Wurtsmith NETTS test location successfully provided the capability to operate and maintain a national field research and demonstration facility for advanced technologies for: site characterization, decontamination of hazardous wastes, and remediation of spill and disposal sites. Recent efforts have provided evidence from more than 10 sites at the former Wurtsmith AFB, confirming the intrinsic bioremediation of fuel and chlorinated mixtures in both aquifer materials and groundwater. These accomplishments will be built on through the support provided to further bioremediation demonstrations at the NETTS location at the former Wurtsmith AFB.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program — Dover AFB, DE; CU-866

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Ms. Alison Thomas

FY 1998 FUNDS: $1,100K

OBJECTIVE: This NETTS National Test Location, which is managed by the Air Force Research Laboratory, provides test sites for the application of characterization and remediation technologies to soil and water contaminated by chlorinated solvents. Its centerpiece is the Groundwater Remediation Field Laboratory (GRFL). The GRFL consists of isolated, well-monitored, in-situ controlled release test cells, in which mass-balance studies of the fate, transport and remediation of Dense Non-Aqueous Phase Liquids (DNAPLs) may be performed, weather protection, office space and a small analytical laboratory.

BENEFIT: The GRFL is a unique resource, the primary purpose of which is to provide contained release cells for DNAPL research and development that avoid making the gross assumptions that would be necessary if experiments were conducted in previously contaminated aquifers. DNAPLs are immiscible with and denser than water, and when spilled on the ground, migrate below the water table. Once below the water table, they are difficult to locate and remove. Currently there are no acceptable methods for removing or treating DNAPLs. These technologies must be developed to protect the public from the potential health risks associated with DNAPLs in drinking water.

TECHNICAL APPROACH AND RISKS: Operations consist of long-term monitoring of the site, as well as project support to include injection of the constituent (Trichloroethylene primarily), demonstration of innovative technologies, and disposal of a minimal amount of waste from the tests. The GRFL program consists of construction of a maximum of five test cells spaced approximately 50 feet apart and constructed and operated in a way to minimize the potential for environmental contamination. Basic design consists of interconnected, steel barrier piling sections (2 feet width) forming a rectangular pattern (test cells will range in size up to 1800 square feet). By driving the sheet piling 3-5 feet into the clay aquitard (approximately 30 - 40 feet from the surface), a coffer is formed which prevents vertical and lateral migration outside the confines of the box. There is an additional secondary containment coffer surrounding the primary coffer, which is similarly sealed at the bottom and at each joint. The annulus between the cells is filled with water to produce an inward hydraulic gradient. The annulus and inner cell are continuously monitored for leakage. There are both upgradient and downgradient monitoring wells outside the secondary coffer. Other sheet pile designs to be considered include geomembrane and grout type barriers. Risks are minimal for the program as designed and can be controlled. Primary risk is that introduced

material will escape and contaminate an aquifer. Vertical migration is retarded very well by a twenty foot thick underlying clay layer with a hydraulic conductivity four orders of magnitude less than the overlying strata. Double sheet piling, grouting, monitoring, developing emergency pump-and-treat system, and distance to the nearest potential users of the aquifer virtually eliminate the risk from lateral migration. A worst-case risk analysis has shown that risk of significant aquifer and surface water contamination and human health impact is negligible even if no barriers are emplaced, cleanup is not attempted, and the TCE source area is left in place indefinitely. The process for obtaining permits for contained releases has been worked out and it is expected to take less than 90 days per permit application.

ACCOMPLISHMENTS: The Dover NETTS test location successfully provided the capability for application of characterization and remediation technologies to soil and water contaminated by chlorinated solvents. Activity at Dover NETTS test site during 1997 was aimed toward optimizing the containment of DNAPL controlled release experiments and included:

- ***Jet Grouting:*** A public-private partnership called the Department of Energy (DOE) Barriers Group has tested cost effective impermeable barrier technologies at the DNTS. High pressure jetting work began in 1997 to demonstrate feasibility of the technology. Work will continue through 1998 to construct a DNAPL resistant barrier.
- ***Double Nested EPA Cell:*** This is a cell configuration to host a SERDP funded, three year series of demonstrations being managed by the Air Force Research Laboratory (AFRL) and the Environmental Protection Agency (EPA) to demonstrate chemical flushing techniques for removing the DNAPL sources of groundwater contamination. Two conventional Waterloo barrier cells are surrounded by a single outer containment barrier allowing for maintenance of an inward hydraulic gradient to contain experiments.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: Bioremediation of Energetic Materials; CU-886

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Ms. Alison Thomas

FY 1997 COMPLETED PROJECT

OBJECTIVE: A wide variety of sites in the U.S. and Europe are extensively contaminated with Dinitrotoluene (DNT). Nitroaromatic contamination can be attributed to past production and demilitarization activities. Most of the subsequent wastewater and washout was discharged to unlined lagoons, resulting in soil and groundwater contamination. The Department of Defense (DoD) has identified more than 1,200 explosive contaminated sites. The objective was to provide a bioremediation technique to degrade DNT-contaminated groundwater and soils. In accordance with the DoD's Project Reliance, the Air Force's nitroaromatic research will transition to the U.S. Army.

BENEFIT: This project developed a destructive bioremediation process for nitroaromatic compounds, specifically DNT. The process complements the U.S. Army's nitroaromatic remediation "tool box," which is tailored to site specific needs. The knowledge gained will facilitate the aerobic degradation of the other more troublesome nitroaromatic compounds like trinitrotoluene (TNT).

ACCOMPLISHMENTS: Scientists at the Air Force Research Laboratory (AFRL) have isolated several microbes that utilize 2,4-DNT as a growth substrate. The microbes have the ability to completely degrade the nitroaromatic compound to innocuous compounds (i.e., carbon dioxide and water). Bench-scale bioreactor studies were completed to determine degradation rates, nutrient and oxygen requirements. Field work has been initiated in FY97 at the Volunteer Army Ammunition Plant (VAAP) to determine the performance and costs for utilizing a fluid bed reactor to degrade DNT contaminated groundwater.

TRANSITION: The project was transferred under the management of CU-720 for the field demonstration portion of the research effort. Results from the successful field demonstration will complement the U.S. Army's nitroaromatic remediation "tool box." Knowledge gained will facilitate the aerobic degradation of the other more troublesome nitroaromatic compounds like TNT.

PROJECT SUMMARY

PROJECT TITLE & ID: Natural Attenuation of Explosives in Soil and Water Systems at DoD Sites; CU-1043

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Judith C. Pennington

FY 1998 FUNDS: $800K

OBJECTIVE: Natural attenuation may be an attractive alternative to more expensive remediation technologies at sites that meet well-defined selection criteria, acceptable risk levels, and that satisfy specific regulatory concerns. However, a significant unanswered question associated with natural attenuation is what processes are relevant and require monitoring to assure that attenuation is effective. Application of existing biomarker and stable isotope technology to in-situ monitoring for natural attenuation of explosives holds the greatest promise for addressing this question. Specific objectives of this project are to (a) identify partner(s) for investigating potential biomarkers, (b) initiate development of mesocosms, and (c) develop an approach for the application of stable isotopes to natural attenuation monitoring.

BENEFIT: Development of effective biomarkers for monitoring natural attenuation will permit application of this technology to sites meeting appropriate selection criteria. Cost of pump-and-treat remediation is approximately $300 per ton, while natural attenuation cost is estimated to be $30 per ton. In addition to the significant cost-saving potential, this project will provide support for and become an integral part of an ESTCP-funded effort for demonstrating natural attenuation of explosives.

TECHNICAL APPROACH AND RISKS: Emphasis will be placed on identifying effective biomarkers, such as microbial deoxyribonucleic acid (DNA) and/or lipid signatures, and stable- isotope techniques that indicate degradation of explosives. State-of-the-art capabilities for these technologies exist at several universities and are under development at Waterways Experiment Station (WES). Therefore, identification of a university partner and development of mesocosms at WES will be critical first tasks. The third task will be formulation of a specific approach for this project which effectively integrates the project into an existing demonstration project on natural attenuation funded by the Environmental Security Technology Certification Program (ESTCP).

ACCOMPLISHMENTS: A field demonstration has been initiated in FY97 at Louisiana Army Ammunition Plant, and has included refinements in groundwater sampling techniques, extensive groundwater monitoring and development of a three-dimensional numerical model to visualize the contaminant plume and predict its future fate. Results to date demonstrate generally declining concentrations of explosives in groundwater over time. Although no geochemical parameters correlate well

with degradation rates of explosives, gradual microbial degradation of RDX and removal of trinitrotoluene (TNT) have been demonstrated with material from the site. Both microbial DNA and lipids have been used to relate microbial degradation potential, microbial community structure and changes in explosives concentrations spatially. A protocol which addresses selection, implementation and regulatory issues associated with natural attenuation of explosives is in draft.

TRANSITION: This project will transition widely to Department of Defense (DoD) sites contaminated with explosives. The development of effective biomarkers for monitoring natural attenuation will permit application of this technology to sites meeting appropriate selection criteria. Furthermore, appropriate selection criteria will lead to enhanced acceptance of remediation technologies with regulatory agencies and other users concerned with the ultimate safety and environmental effects of explosives.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of Neural Networks Coupled with Genetic Algorithms to Optimize Soil Cleanup Operations in Cold Climates; CU-1049

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Cold Regions Research and Engineering Laboratory - Hanover, VT

PRINCIPAL INVESTIGATOR: Dr. John M. Sullivan

FY 1998 FUNDS: $200K

OBJECTIVE: This project has two objectives for site characterization and contaminant fate, transport, and remediation analysis for site cleanup alternatives. The first objective is the automatic decomposition of Ground Penetrating Radar (GPR) signals into stratigraphic layers using Neural Networks. GPR can probe the subsurface non-invasively at high resolutions. However, methods for quantitative interpretation of these data are sparse. We propose to train Neural Networks, which are ideally suited for pattern recognition, to recognize various stratigraphic layer configurations. With this tool in place, enhanced quantitative site conceptualizations become available. The second objective is the development and implementation of a rapid solution strategy for analyzing selected remediation/monitoring alternatives using Neural Networks coupled to Genetic Optimization routines. The Neural Networks will be trained to recognize a contaminant distribution as a function of the boundary conditions. The Genetic Optimization routines will be developed for decision analysis of various remediation alternatives and monitoring strategies based on the simulated behavior predicted by the Neural Network. The coupling of these applied research areas can potentially yield an analysis technique that holds the promise of illuminating the subsurface stratigraphy and the deployment of an optimum remediation strategy.

BENEFIT: The expected benefits of this project are an accurate, non-invasive tool for site conceptualization and an optimized remediation and monitoring deployment plan for sites where cleanup and monitoring of groundwater is required. The ability to characterize a site will increase by two orders of magnitude from current practices. The gains realized in predicting subsurface contaminant flow would be an order of magnitude. The optimized deployment routines could reduce the remediation and monitoring cost of a contaminated site by one third.

TECHNICAL APPROACH AND RISKS: Neural Network Models will be trained to decompose GPR signals into stratigraphic layers such as top-of-permafrost, bottom-of-permafrost, water table, and top-of-bedrock. Extensive GPR and ground-truth borehole data collected on several sites at Fort Wainwright, AK, and elsewhere will be used for training the Neural Network, f the propagation of GPR signals derived from the traditional governing equations for electromagnetic wave propagation. This approach has been successfully applied by the investigators to non-destructive acoustic-wave analysis of composite materials. Electromagnetic wave propagation in natural soils is a much more complex problem,

for which these techniques are as yet untested. If successful, this modeling strategy can be extended for non-invasive evaluation of the subsurface in general, including such stratigraphic features as boundaries between sand, silt and clay. Using the same test sites at Ft. Wainwright, AK, a Neural Network system coupled with a genetic optimization algorithm will be employed to assist in the decision analysis of alternative remediation treatments and of various configurations within a remediation treatment.

ACCOMPLISHMENTS: In FY97, additional GPR field data was collected at Fairbanks and Anchorage, AK. This GPR field data was compared with GPR signal propagation in soils simulated numerically (in 3-D). The Report on Stratigraphy Determination based on field data was submitted for Cold Regions Research and Engineering Laboratory (CRREL) review.

TRANSITION: The project intends to transition the optimized deployment routines to be developed and tested under this project beyond the cold regions applications to many contaminated sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Multisensor Data Fusion for Detection of Unexploded Ordnance; CU-1052

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Ernesto Cespedes

FY 1998 FUNDS: $100K

OBJECTIVE: The first objective of this project is to develop a better understanding of the environmental factors and phenomenologies that dictate success and failure in subsurface anomaly detection through a careful study of controlled field tests involving several sensor technologies. The primary source of field data will be the U.S. Army Environmental Center and the contractors who participated in the Jefferson Proving Ground (JPG), IN, Phase I, Unexploded Ordnance (UXO) Advanced Technology Demonstrations. The second objective is to identify the most promising data analysis, or data fusion, approach to improve UXO detection and to demonstrate detection improvement through the fusion of multiple data sets from the previously mentioned field tests.

BENEFIT: The successful conduct of the elements of this research project will place the U.S. Army Corps of Engineers in a position to assemble a prototype multisensor UXO detection platform along with the software necessary to accomplish fusion of the enormous amount of data such a platform will develop. Follow-on commercialization of this platform will provide a tremendous financial savings over current man-in-the-loop UXO detection and clearance operations that focus on areas that are very limited in physical size.

TECHNICAL APPROACH AND RISKS: Two distinct elements are being pursued:

a. Phenomenology Studies. While the JPG UXO technology demonstrations provided an unbiased ranking of current technology performance in the field, it did not provide a mechanism for a scientific evaluation of why particular systems did or did not perform well. The first element of this project would be to support such an evaluation. This would be accomplished by forming an honest-broker technical review committee made up of government scientists who would solicit genuine technical evaluations of their system's performance from several of the participants of the Technology Demonstrations. The review committee would critique each of these self-examinations and prepare a report that would address many of the phenomenological issues that affect sensor performance in this environment and provide general guidance for system improvements that would feed the effort to develop a multisensor detection platform. Care will be taken not to infringe on the proprietary rights of the technology demonstrations participants.

b. Data Fusion Algorithm(s). The second element of this project will focus on the combination of data from several sensors to optimize detection system performance. This effort would begin by examining more closely any attempts at data fusion performed by JPG demonstration participants who utilized multiple sensors. A prototype data fusion algorithm would then be developed that would be tested on JPG data taken from both multiple sensor platforms and from multiple sensors used by different participants that could be spatially coregistered. The final product of this effort would be a model that could easily be adapted to the fusion of data from the array of sensors that would serve as the prototype UXO detection system.

The greatest technical risk lies with acquiring data of sufficient quantity and quality to accomplish the stated objectives. In concert with the concerns of data quality is the issue of being able to acquire physics-based models for predicting sensor performance that possess enough flexibility and sophistication to deal with the phenomenologies that govern target/sensor/background interactions.

ACCOMPLISHMENTS: In FY97, the U.S. Army Waterways Experiment Station (WES) researchers have developed a prototype multisensor data integration algorithm for magnetic and Electromagnetic (EM) induction datasets and initiated implementation using Defense Advanced Research Projects Agency (DARPA) datasets, as well as the development of the geographic information system (GIS) system for DARPA UXO datasets that includes site layout, topographical, vegetation, and environmental data, and target locations. Researchers have: 1) completed acoustic resonance signature measurements over inert ordnance items (preliminary analyses indicates diagnostic resonances for some ordnance items but not for others); 2) solved problems with stray currents in conducting (Aluminum) but non-ferrous magnetic sensor mounts for magnetic measurements over inert ordnance; 3) acquired Naval Research Laboratory Multi-Sensor Towed Array Detector System (NRL MTADS) data sets over known inert ordnance at various depths and orientations; 4) validated WES magnetic modeling software by correlation with the MTADS data sets; 5) examined various data integration techniques with the MTADS data sets (e.g., magnetic versus magnetic induction phase-space plots for various inert ordnance items); and, 6) initiated planning for UXO technology workshop that will include Principal Investigators (PIs) from all ongoing SERDP UXO projects and the new FY98 starts.

TRANSITION: The project intends to pursue follow-on commercialization of the multisensor UXO detection platform to provide a tremendous financial savings over current man-in-the-loop UXO detection and clearance operations that focus on areas that are very limited in physical size.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Simulators for In-Situ Remediation Evaluation, Design, and Operation; CU-1062

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Mark Dortch

FY 1998 FUNDS: $850K

OBJECTIVE: The ultimate goal in remediation modeling is to minimize remediation costs and environmental and human risks while maximizing cleanup. Toward this end, the general goals of this project are: (1) to develop reliable simulators for promising technologies of interest to Department of Defense (DoD), Department of Energy (DOE), and the regulatory community, and (2) to provide efficient access to multiple remediation simulators through a common user environment amenable to multi-disciplinary cleanup teams. A common, graphical user environment has been developed for these simulators; it is the DoD Groundwater Modeling System (GMS). The GMS provides conceptualization, parameterization, visualization, and animation capabilities. Additionally, GMS extensions, either ongoing or planned, will provide capabilities for conducting remediation, uncertainty, optimization, and cost analyses. The primary technical objectives of this project are to: (1) develop/enhance state-of-the-art remediation simulators for the following technologies: in-situ bioremediation; surfactant-enhanced bioremediation; electrokinetic-enhanced bioremediation; electrokinetic-enhanced mobilization of metals; natural attenuation of petroleum hydrocarbons; natural attenuation of explosives; in-situ chemical treatment; surfactant/cosolvent flushing to recover Non-Aqueous Phase Liquids (NAPLs); soil vapor extraction and bioventing; and air sparging; and (2) verify these simulators against available laboratory and field data; and (c) incorporate these simulators into the GMS to provide DoD, DOE, and other users with the computational ability to assess the tradeoff between environmental risk (cleanup level) and cost-effectiveness for a variety of cleanup technologies prior to their implementation.

BENEFIT: The GMS-based simulators will permit efficient evaluation of multiple remediation technologies for site-specific conditions, allowing selection of effective and cheaper cleanup actions. Such simulators are needed to support advocacy for biogeochemically complex alternatives that are faster, more effective, and/or more cost-efficient than traditional methods. Simulators will improve the remedial design by permitting cleanup specialists to consider multiple scenarios that could increase cleanup effectiveness.

TECHNICAL APPROACH AND RISKS: Remediation simulator development will proceed along three paths, in order of priority: (1) utilize existing, proven remediation simulators where available and consistent with project goals, (2) modify promising groundwater codes to simulate additional technologies as appropriate, or (3) develop new codes as required for efficient simulation of innovative technologies.

All simulators will be verified against available laboratory and field data. Where data permit, the simulators will be applied for National Environmental Technology Test Sites (NETTS). Results of these evaluations and the simulator codes will be documentation. Each simulator will be implemented in the GMS. This project strongly leverages technical partnering and collaboration with ongoing and proposed basic and applied research in subsurface flow, contaminant fate/transport, remedial methods, remediation simulation under heterogeneous subsurface conditions, GMS-user environment development, and high performance computing in environmental quality modeling. Technical risk issues involve: (1) uncertainty regarding key processes in complex remediation technologies; (2) the scarcity of experimental or field data for innovative technologies; and (3) the general adequacy of differing computational resources on which to run complex models efficiently. Leveraging against the new Common High-Performance Scalable Software Initiative and Army High-Performance Computing efforts will address several of the high-performance computing issues associated with simulator development and execution.

ACCOMPLISHMENTS: In FY97, the U.S. Army Waterways Experiment Station (WES) researchers have worked toward developing the various modeling codes. Work on Sequential Electron Acceptor Model in 3D (SEAM3D) included improvements for bioremediation modeling with the initiation of reconnaissance work on selecting a verification test case for SEAM3D at Wurtsmith Air Force Base (AFB). Work was initiated on modeling the funnel and gate In-Situ Chemical Treatment (ISCT) (zero valent iron method) test site at Dover AFB using the Operator Splitting in 3D (OS3D) ISCT code. Improvements were made to the Non-Isothermal Unsaturated/Saturated F&T in 3D (NUFT3D) multiphase flow and transport code to better handle heterogeneities, and work continued on implementation of NUFT3D into the GMS. A model for the Dover AFB Funnel and Gate System, based on information provided on site characterization and the Environmental Protection Agency (EPA)-Athens on zero-valent iron chemistry, was developed with OS3D to simulate both zero-valent iron alone and zero-valent iron with pyrite. Work on incorporation of SEAM3D into the GMS was continued, as well as the initiation of merging SEAM3D with the new version of Modular Transport in 3D (MT3D). This new version of MT3D (renamed MT3DMS) was recently completed by University of Alabama researchers to handle mobile and immobile multi-species transport. Planning was conducted for application of SEAM3D/MT3DMS to the Natural Attenuation Test Site (NATS) at Columbus AFB where Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) and bromide data have been collected since December 1995. Additionally, planning was conducted for another verification application of SEAM3D to data from the National Center for Integrated Bioremediation Research and Development (NCIBRD). NCIBRD has several sites of interest at the former Wurtsmith AFB in Oscoda, MI.

TRANSITION: The project will transition the GMS-based simulators directly to users that include DoD, DOE, EPA, and other groundwater and environmental professionals involved in hazardous waste site cleanup. Use of these remediation simulators will allow more reliable comparison between cleanup level (its duration, environmental risk level) and the cost of each level of cleanup.

PROJECT SUMMARY

PROJECT TITLE & ID: Bioenhanced In-Well Vapor Stripping to Treat Trichloroethylene; CU-1064

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Dr. Mark N. Goltz

FY 1998 FUNDS: $560K

OBJECTIVE: The objective of this project is to demonstrate the potential of combining two innovative, recently demonstrated, remediation technologies, in-well vapor stripping and in-situ aerobic cometabolic bioremediation, to cleanup an area contaminated with separate phase [Dense Non-Aqueous Phase Liquid (DNAPL)] and dissolved phase Trichloroethylene (TCE).

BENEFIT: The most obvious benefit is that this combination of technologies offers the potential of reducing, in-situ contaminant concentrations at a DNAPL contaminated site over three orders of magnitude, something which heretofore has never been demonstrated. The fact that the technologies are applied in-situ minimizes risk to human and environmental receptors, as well as reduces the costs of pumping water to the surface, treating it, and disposing of it. The technologies can be used at sites with any volatile, separate-phase contaminant that is susceptible to bioremediation by aerobic cometabolism (TCE, Dichloroethylene (DCE), vinyl chloride, dichloromethane, etc.).

TECHNICAL APPROACH AND RISKS: Under this project, an in-well vapor stripper will be installed in a DNAPL (TCE) contaminated "hot spot zone", upgradient from a downflow biotreatment well. The TCE will be emplaced in a cell at the Groundwater Remediation Field Laboratory (GRFL) at Dover AFB. In operation, the in-well vapor stripper will use air-lift pumping to pump contaminated water from the lower portion of the aquifer to a screened interval above and below the water table. Approximately 90-99 percent of the volatile organic compound (VOC) will be stripped out of the water into the gas phase, which will subsequently be treated using granular activated carbon. The treated water leaving the upper screen of the in-well vapor stripper will flow to the upper screen of the biotreatment well. Water entering the biotreatment well will be pumped down through the well, where a primary substrate such as toluene will be added. Oxygen may also need to be added in the biotreatment well, though it is possible that the oxygen dissolved during the in-well vapor stripping will be sufficient to support the aerobic bioremediation process. After addition of the primary substrate (and possibly, oxygen), the water will be injected into the aquifer through the lower screened interval, where indigenous microorganisms can aerobically metabolize the primary substrate and cometabolize the contaminant. A portion of the water leaving the bioactive zone will recirculate back to the lower screen of the in-well vapor stripper for further treatment. The combined technology of bioenhanced in-well vapor stripping should remove as much or more TCE from the groundwater than would be removed compared to conventional technologies (e.g., pump-and-treat).

Because each technology is currently being demonstrated independently, the main technical challenge and risk comes from the integration of the two, which can be dealt with by adjusting various operating parameters (e.g., gas flow in the stripping well, primary substrate feed in the biotreatment well, water flow rates) to optimize performance. Another challenge will be to scale down the two technologies (in-well vapor stripping and in-situ bioremediation), which are currently being demonstrated at full-scale in the field at Edwards Air Force Base (AFB), for analysis within the confines of a GRFL cell. This scaling-down will be accomplished through modeling, by combining fate and transport models that have been developed to simulate the two technologies. A last challenge will be to demonstrate the system at a site that has geochemical conditions considerably different from the conditions encountered at Edwards AFB. In particular, the high iron content in the groundwater at the GRFL may present difficulties that may require adjustments to the system.

ACCOMPLISHMENTS: In FY97, design procedures were pursued by researchers prior to the field trial to be conducted at the Groundwater Remediation Field Laboratory (GRFL) at Dover AFB, Delaware. A numerical model has been used to design the demonstration which simulates recirculating groundwater flow; transport of dissolved TCE, toluene, and oxygen; cometabolism; and in-well volatilization of dissolved TCE. The constituents simulated have been pure-phase and dissolved TCE, toluene, dissolved oxygen, and biomass. Preliminary modeling studies have been completed, assuming instantaneous biodegradation of contaminant in the biotreatment well. Preliminary site-specific design studies showed that the technology could be demonstrated in the confines of a GRFL field demonstration test cell. Core and water sampling were accomplished inside and outside the field test cell which will be used for the demonstration.

TRANSITION: If successful in the test cell demonstration, this project will transition to a full scale demonstration that combines the two remediation technologies, in-well vapor stripping and in-situ aerobic cometabolic bioremediation, to cleanup an area contaminated with separate phase (DNAPL) and dissolved phase TCE.

PROJECT SUMMARY

PROJECT TITLE & ID: Low-Frequency Ultra-Wideband Boom Synthetic Aperture Radar (Boom-SAR) for Remote Detection of Unexploded Ordnance; CU-1070

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Army Research Laboratory - Adelphi, MD

PRINCIPAL INVESTIGATOR: Mr. Marc Ressler

FY 1998 FUNDS: $700K

OBJECTIVE: The goals of this project are: 1) to determine the applicability of low-frequency ultra-wideband (UWB) Synthetic Aperture Radar (SAR) for detecting and discriminating surface and subsurface unexploded ordnance (UXO); 2) to refine and validate electromagnetic models that can be used to extrapolate UWB SAR performance to other environmental conditions (soils); and, 3) to develop detection algorithms for separating UXO from clutter.

BENEFIT: The knowledge gained by this effort will significantly enhance our understanding of the phenomenology of UXO characterization using low-frequency UWB SAR. This effort will also help to determine the utility of the Army Research Laboratory (ARL) BoomSAR for surveying large regions and detecting and discriminating various surface and subsurface UXO. It is expected that this technology will achieve rapid survey speeds/coverage rates while allowing safe standoff distances during operation; it will also significantly improve the detection, monitoring, and risk management activities at cleanup sites.

TECHNICAL APPROACH AND RISKS: Currently, methods for detecting UXO involve laborious ground surveys that are slow, dangerous, and impractical for dealing with vast UXO-contaminated lands. Advanced technologies are required which are quicker, safer, and more cost-effective than current approaches. SAR is an advanced technology that offers significant potential for quickly and safely detecting UXO. The ARL will use their precision measurement asset, called the BoomSAR, in the execution of this project. The BoomSAR is a fully polarimetric radar that operates across a 1-GHz-wide band, from 25 MHZ to 1 GHz. This bandwidth contains low frequencies needed for ground penetration, while maintaining higher-frequency coverage for high-resolution imagery. The ultra-wide bandwidth provides measured range resolution of 0.15 m; the aperture length provides cross-range resolution of 0.15 m. The radar is mounted on a boom-lift that can operate at heights of 5 to 45 m while moving at 1 km per hour, allowing the radar to operate in a strip-map SAR mode.

ARL's BoomSAR will be used to collect high-quality precision data to support phenomenological investigations of electromagnetic wave propagation through dielectric media. These investigations, in turn, will support the development of algorithms for target detection. Data will be collected at two UXO test sites that have been seeded with a comprehensive variety of inert UXO.

This project is minimizing technical risk by leveraging the significant investments of ARL's 6.2 Army tech base and Defense Intelligence Agency customer funds. The ARL has played a significant role in understanding the potential of low-frequency, ultra-wideband synthetic aperture radar (UWB SAR) technology to detect targets concealed by foliage and subsurface targets. In addition, ARL has been working closely with other agencies, such as Defense Advanced Research Projects Agency, Air Force Research Laboratory, Naval Surface Weapons Center, Defense Special Weapons Agency, and Defense Intelligence Agency, to realize the full potential of this advanced technology.

ACCOMPLISHMENTS: In FY97, ARL researchers have used their low-frequency, ultra-wideband (50 MHZ - 1200 MHZ) SAR to enhance the ability to detect buried UXO. While operating from heights up to 150 ft. atop a mobile boom platform, this side-looking ground-penetrating radar can detect buried targets down to several feet below the surface. Results of preliminary investigations concluded that the radar image texture and frequency-dependent scattering from some UXO targets could be exploited in the development of automatic target detection algorithms. To support further investigations, a UXO test site containing over 600 inert ordnance items has been established at Yuma Proving Ground, Arizona. Precise location and orientation information was recorded for each bomb, mortar, artillery shell, rocket and submunition to give researchers a better understanding of the phenomenology associated with UXO target scattering and to evaluate and modify data processing programs more accurately.

TRANSITION: The technology developed under this project will transition to users at active test and training ranges, Base Realignment and Closure (BRAC) and formerly used defense (FUD) sites, and numerous foreign countries requiring advanced technologies for locating UXO.

PROJECT SUMMARY

PROJECT TITLE & ID: Unexploded Ordnance (UXO) Detection by Enhanced Harmonic Radar; CU-1071

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: National Reconnaissance Office

LAB: National Reconnaissance Office - Chantilly, VA

PRINCIPAL INVESTIGATOR: Dr. Ronald Stocks

FY 1998 FUNDS: $450K

OBJECTIVE: The objective of this effort is to design, fabricate, and test a third harmonic radar to determine its efficiency in detecting surface and buried unexploded ordnance (UXO) of all sizes and types. In addition, the radar also will produce a capability to produce high resolution images showing their locations. This proposal builds on earlier work on harmonic radar and outlines the development and demonstration of a high resolution, medium range (3-4 km standoff distance) impulse driven synthetic aperture radar.

The problem of UXO detection has become both acute domestically and worldwide. In the U.S. specifically, there are over 900 sites (11 million acres) of potentially UXO contaminated land of varying terrain, foliation, and topography (including 50 underwater sites). UXO cleanup represents a huge and costly problem. To date, methods of detection and remediation are at best slow and expensive and at worst crude and highly dangerous. The advantage of improved target detection techniques (especially airborne) that can aid in rapid, cost efficient and safe detection are obvious.

BENEFIT: The immediate benefit to be realized from this effort is a prototype system with a demonstrated capability to remotely detect and locate surface and shallow-buried UXO. If successful, this effort will provide the UXO remediation community with a capacity not now available. The radar system will be capable of standoff "broad area" search at relatively low cost and provide greater efficiency in removal and/or cleanup. The radar system will be an operational prototype that could be used for subsequent contractor-supported operations. The radar could also be modified to fit on a variety of aircraft of helicopter platforms. In addition, this technology should be of interest to a variety of other Department of Defense (DoD)/Department of Energy (DOE) environmental, military, and law enforcement objectives.

TECHNICAL APPROACH & RISK: The project is divided into two phases, a ground phase and an airborne phase. The final result of this effort will be a prototype third harmonic radar system hosted on an aircraft for the detection and mapping of surface and subsurface mines and UXO. This system will be available for operational deployment if desired.

The critical elements of this UXO detection system are: 1) the third harmonic returns; 2) the ability to produce usable images for analysis; and 3) the fusion of this information with that from other sensors. The major reason that Ground Penetrating Radar (GPR) and other radars have not lived up to some expectations is not because of the lack of power, resolution or penetration capabilities. Rather, the problem lies with the lack of specificity of the radar return. Natural clutter, depressions, soil strata, etc., produce their own returns that mask, obscure or compete with those targets of interest. Unlike higher frequency radars, typical foliage and ground penetrating radars produce images that are so cluttered that they are difficult to interpret.

Image discriminants have proved elusive and even highly sophisticated Automated Target Recognition algorithms have difficulty in discrimination. Third harmonic radars provide that discriminant. The unique radiation characteristic potentially can be exploited to completely suppress the natural clutter.

The production of images that detect and accurately locate targets of interest has not been previously attempted. However, several years of effort with other radar systems have produced a wealth of image processing algorithms that will form the foundation of the image processing requirement. In addition, this project intends to make use of the SERDP National Environmental Technology Test Sites to the maximum degree possible.

ACCOMPLISHMENTS: In FY97, this project responded to a Scientific Advisory Board (SAB) directive to perform an initial proof-of-concept demonstration prior to pursuing the balance of the project's proposed objectives. This demonstration included the placing of representative UXO samples inside a wooden box filled with sand, and placing the wooden box inside an anechoic chamber. Testing of the third harmonic radar's detection capabilities was performed. The proof-of-concept was successful and the project intends to continue with its efforts in FY98.

TRANSITION: The technology developed under this project will transition to users at active test and training ranges, Base Realignment and Closure (BRAC) and formerly used defense (FUD) sites, and numerous foreign countries requiring advanced technologies for locating UXO.

PROJECT SUMMARY

PROJECT TITLE & ID: Using Mode of Action to Assess Health Risks from Mixtures of Chemical/Physical Agents; CU-1073

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Department of Energy

LAB: Pacific Northwest National Laboratory - Richland, WA

PRINCIPAL INVESTIGATOR: Dr. Richard Bull

FY 1998 FUNDS: $410K

OBJECTIVE: Mixtures of carcinogenic chemicals are a major problem in groundwater plumes and soils on Department of Defense (DoD) and Department of Energy (DOE) facilities. While there is frequently data available for interactions between chemicals to judge risks from short term exposures, data that describes how interactions influence the development of cancer are very rare. This is largely because of the high costs associated with conducting complex interaction studies over the lifetime of experimental animals. Therefore, it is important that the limited resources that are available for studying interactions be directed towards the development of general principles that can be applied to a wide variety of circumstances.

The specific technical objectives:

a) To provide a scientific basis for estimating the risk for liver cancer induction by mixtures of chlorinated hydrocarbon solvents in hazardous waste sites and contaminated groundwater.
b) Test the hypothesis that interactions between non-genotoxic modes of action can be meaningfully predicted from knowledge of the mode of action and the dose-response relationships found with the individual components of the mixture. To limit the cost of this initial effort, the test will be limited to tertiary mixtures in which the dose of only one compound will be varied dichloroacetate (DCA).
c) Based on these studies an experimental design will be developed to validate the approach using solvents that independently generate the metabolites responsible for liver cancer induction.

BENEFIT: Because of the high cost associated with conducting research to examine biological interactions, the study of every potential interaction of environmental concern is not feasible. This research is directed towards the development of general principles that can be applied to a wide variety of circumstances. The benefits to DOE and DoD from the work proposed are: 1) data bases that can be directly used to assess the risks from mixed exposures to DCA or TCA whether they arise as metabolites from a single solvent [e.g., Trichloroethylene (TCE)] or from a mixture of solvents, 2) the data necessary to see how these metabolites interact with a cytotoxic solvent (carbon tetrachloride), and 3) a test of the hypothesis that hazards associated with mixtures of carcinogenic chemicals can be addressed by simply identifying the mode of action and knowing the dose-response relationships for the individual chemicals.

TECHNICAL APPROACH & RISK: The hypothesis this project intends to test is whether classifying the modes of action represented in a mixture and knowledge about the dose-response characteristics involved in eliciting a particular mode of action will provide a simpler and more accurate means of predicting the hazards that the mixture poses over a range of exposure situations. Whereas the number of chemicals present in the mixture may be large, the number of modes of action responsible for these effects are small. Each mode of action may have dozens of mechanisms that might contribute to changes in cell birth/death processes, but establishing mechanisms for every chemical is very expensive. The modes of action represented by the three chemicals proposed for study are general to chemical carcinogenesis. Thus, the approach that would result from proving our hypothesis should be broadly applicable to any mixtures of chemical and/or physical causes of cancer. The top seven chlorinated hydrocarbon solvents found on DOE facilities produce liver cancer by non-genotoxic mechanisms. Two others are clearly genotoxic. Therefore, all modes of action are represented among these compounds. The occurrence of the genotoxic compounds is much less frequent and generally at much lower concentrations than the first seven compounds. Their cleanup levels are less controversial because it is difficult to refute low dose linearity in response for such chemicals and their concentrations rarely exceed drinking water standards of the Environmental Protection Agency (EPA).

Our approach is to test the feasibility of utilizing modes of action to predict the risks posed by exposures to complex mixtures by first investigating key interactions in binary mixtures and using that data to determine whether we can predict the results of a limited number of tertiary mixtures. The results of these studies can be directly applied to modeling the generation of DCA and Trichloroethane (TCA) from all of the other problem solvents on DoD and DOE sites, including perchloroethylene, 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1,1,2-tetrachloroethylene and 1,2-dichloroethylene. The mechanisms of how these chemicals act will vary depending upon how much TCA and DCA they generate. Since DCA and TCA produce tumors with differing phenotypes, have different cell replication properties, and activate distinct mechanisms very specific questions can be tested experimentally with both binary and tertiary mixtures. The toxicodynamic data that will be obtained on DCA and TCA will provide a base for assessing risks from mixtures of virtually all of the solvents that are frequent contributors to both Federal and non-Federal waste site problems.

ACCOMPLISHMENTS: This project commenced late in FY97.

TRANSITION: The project has a transition plan that includes: 1) insuring utilization of the data through extensive interaction with EPA; 2) establishing the hypothesis that interactions between environmental carcinogens can be understood on the basis of their individual modes of action; and 3) expanding the concept to other important environmental mixtures.

PROJECT SUMMARY

PROJECT TITLE & ID: Value-Added Site Monitoring & Infrastructure Maintenance for In-Situ Bioremediation; CU-1080

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Environmental Protection Agency

LAB: University of Michigan, National Center for Integrated Bioremediation Research & Development - Oscoda, MI

PRINCIPAL INVESTIGATOR: Dr. Michael Barcelona

FY 1998 FUNDS: $395K

OBJECTIVE: The objectives of this project include: the continued serial monitoring of intrinsic bioremediation processes at three fuel and solvent contaminated sites at the former Wurtsmith Air Force Base; the support, maintenance, and supplementation of the data in a relational database management system (RDBMS); and the statistical analysis of the data for spatial and temporal variability, estimates of mass removal rates and indicators of bioremediation process change.

BENEFIT: The project will provide direct benefit to Department of Defense (DoD), Department of Energy (DOE), and Environmental Protection Agency (EPA) by: 1) providing comprehensive field data for intrinsic remediation modeling efforts; 2) allowing more cost effective long term monitoring designs to be developed; and, 3) improving basis for collaboration among technology developers which will mean less redundancy between efforts. An overall benefit will be more cost-effective designs and performance goals for bioremediation of contaminated sites.

TECHNICAL APPROACH & RISK: The technical approach consists of a phased approach to the objectives outlined above. State of the art contaminant and geochemical ground-water monitoring will be continued on a quarterly basis at three fuel and solvent contamination sites which have distinct oxidation-reduction zones. Indicators of corresponding bioremediation indicators and the mass of contaminants associated with aquifer solids will be determined as well. Additional, statistical analyses of the time-series and spatial distribution of contaminants and geochemical conditions will be evaluated for sources of error and variability. Bioremediation performance indicators will be developed in selected oxidation-reduction zones. Several years of data exist for the three study sites which will provide a basis for the use of RDBMS and results of the statistical analyses by leading bioremediation modeling and remedial design groups.

ACCOMPLISHMENTS: Recent efforts have provided evidence from more than 10 sites at the former Wurtsmith AFB, confirming the intrinsic bioremediation of fuel and chlorinated mixtures in both aquifer materials and groundwater. In FY97, this project has pursued the collection of additional data that support this conclusion: the disappearance of dissolved parent compounds, increases in alkalinity, and changes in

electron acceptor/donor concentrations. The apparent completeness of microbial transformation under aerobic conditions for fuels [(e.g., Benzene, Toluene, Ethylbenzene, and Xylene (BTEX)] and reducing conditions for chlorinated alkenes [Trichloroethylene (TCE), Dichloroethylene (DCE)] falls far short of the expected suite of terminal end- products. Results have also demonstrated that aromatic fuel components are degraded to complex mixtures of aromatic acids and phenols under aerobic to suboxic/reducing conditions. In fact, the intermediate metabolite concentrations in the contaminated groundwater are higher than the parent compounds, and even highly-substituted aromatics degrade apparently over this redox range. These accomplishments will be built on through further bioremediation demonstrations at the National Environmental Technology Test Sites (NETTS) location at the former Wurtsmith AFB.

TRANSITION: The results of the continued serial monitoring of intrinsic bioremediation processes will be made widely available to facilitate transition of the project's efforts. The various efforts to ensure dissemination of information will enable further usage by DoD and DOE site managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Genosensor-Based Ecotoxicity Response Assessment; CU-1081

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Department of Energy

LAB: Oak Ridge National Laboratory - Oak Ridge, TN

PRINCIPAL INVESTIGATOR: Dr. Kenneth Beattie

FY 1998 FUNDS: $645K

OBJECTIVE: The objective of this project is to develop cost effective methods and instrumentation for directly monitoring genotoxic exposure in a variety of natural ecosystems. Direct measurements of the in-situ biological responses associated with genotoxic exposure of sentinel species in the environment circumvents the difficult problem of bioavailability, since measurable molecular endpoints in resident species are a direct reflection of ecologically relevant exposure. The project intends to implement emerging biochip technology for in-situ monitoring of molecular endpoints of genotoxic exposure, including DNA damage-inducible gene expression pathways, in soil and water ecosystems.

BENEFIT: Expanded capabilities for ecotoxicity surveillance, incorporating a comprehensive collection of molecular endpoints associated with military-relevant compounds, would greatly facilitate site characterization, risk assessment and monitoring of the progress of remediation efforts at Department of Defense (DoD) and Department of Energy (DOE) installations. Such capabilities for rapid, multispecies biological endpoint monitoring that is ecologically relevant to cleanup of contaminated sites, should provide a rational basis for reduced cleanup costs, addressing the "how clean is clean?" question. The new technology is expected to enable site closures in a shorter period of time, bringing significant long term cost savings.

TECHNICAL APPROACH & RISK: This project intends to employ novel channel glass biosensor chips containing arrays of DNA probes to characterize and monitor the response of soil microorganisms to exposure to genotoxic agents. The biochip device consists of a glass or silicon dioxide wafer containing miniature patches of densely packed pores of 1-10 μm diam., extending through and perpendicular to the wafer surface. DNA probes can be immobilized within individual porous patches at addressable sites across the wafer, to provide a microscopic array of unique nucleic acid hybridization sites. An array of surface-tethered oligonucleotide probes is called a genosensor. The technical objectives of the project will be achieved via the following specific tasks: (i) fabricate channel glass genosensor arrays containing DNA probes specific to currently known bacterial stress response and DNA damage-inducible genes; (ii) use the "stress response genosensor" to characterize the induction of known stress genes in model soil bacteria exposed in the laboratory to various genotoxic chemicals; (iii) utilize a new genosensor- based oligonucleotide fingerprinting strategy to discover new stress response/DNA damage inducible genes; and (iv) initiate ecotoxicity surveillance studies with soil and water samples from DOE and DoD sites. The

main risks (technical challenges) associated with the project include the requirement to extract intact (undegraded) RNA from environmental samples and the low abundance of soil microorganisms deep below the surface. Feasibility studies will directly address these critical issues in order to define the operational limitations and utility of the approach.

ACCOMPLISHMENTS: This is a FY98 New Start.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP) for a large scale demonstration. The long term aim of the project is to install and operate genosensor systems at Oak Ridge National Laboratory (ORNL) and the U.S. Army Waterways Experiment Station (WES) for use in assessing ecological effects of genotoxic exposure at DOE and DoD sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Selective Removal of Heavy Metals from Aqueous Wastes by Electrosorption on Functionalized Carbon Aerogels; CU-1084

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Department of Energy

LAB: Lawrence Livermore National Lab - Livermore, CA

PRINCIPAL INVESTIGATOR: Dr. Tri Tran

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective of this project was to develop novel functionalized carbon aerogel electrodes that are integrated in an electrochemical cell for selective removal of heavy metals. Treatment of large amount of aqueous wastes containing heavy metal ions at many U.S. Department of Defense (DoD) and Department of Energy (DOE) facilities requires considerations of wide ranging technologies with flexible and, sometimes, customized capabilities. One example is the need to remove radioactive Cs^+ from a large background of Na^+ and K^+. Another example is the removal of Resource Conservation and Recovery Act (RCRA) metals from brackish groundwaters or plating shop effluents.

The technical approach involves three integrated major tasks. The primary task is to develop functionalized carbon aerogels that would have a specific affinity for a targeted metal. Four types of carbon aerogel electrodes will be prepared and studied. The conventional resorcinol-formaldehyde- based carbon aerogel electrodes and three modified types of materials treated by thermal activation and chemical modifications (2 methods). Acidic carbon-oxygen complexes can be introduced on carbons by thermal treatment with oxidizing agents (O_2, CO_2, steam) or by chemical treatment in solutions with $KMnO_4$, HNO_3. Chemical treatment via silanization and amidization to introduce compounds such as porphyrin compounds (tetra(p-aminophenyl)porphyrin) will be studied. These modified electrodes are expected to have special affinity for metal cations such as Cr, Co, Cu, Ni and Zn. These novel materials will then be incorporated (second task) in an electrochemical separation cell. The cell dimension will contain active electrode surfaces of 2 inch x 4 inch. The cell is undivided and uses no membranes. The cells are polarized by programmable power supplies that have a voltage range of 0 to 1.2 V with a current range between 0 and 60 A. The third task is to investigate selective removal of 35 ppb Cr(VI) [Lawrence Livermore National Laboratory (LLNL) contaminated source level] from an aqueous solution containing other non-toxic components such as Na^+, K^+, and Ca^{2+}. Total dissolved solids (TDSs) in these solutions are about 500 ppm. The effects of selective removal of Cr and another heavy metal (Co, Cu, Pb, Zn and Ni) will be investigated. The primary risk would be the complicated phenomena associated with competitive electrosorption of a heavy metal and other ions. The fabrication of and the selective separation with functionalized electrodes has not been investigated in the past.

BENEFIT: This project will provide DoD and DOE a novel and promising technology for efficient waste remediation. It has significant implications and applications in a wide range of areas besides metal separation. The project also leveraged SERDP investment in capabilities and knowledge on Capacitive Deionization and its three successful demonstration projects at one DOE and two DoD sites.

ACCOMPLISHMENTS: In FY97, LLNL researchers focused their efforts on finding solutions to the specific needs of DoD and DOE facilities to treat large amount of aqueous wastes containing heavy metal ions. This integrated experimental program has worked toward developing tailored carbon aerogel electrode materials that are modified chemically and physically to enhance the selective separation of a targeted metal from an aqueous stream. The research has begun to demonstrate and/or identify factors affecting selective removal of a model species, Cr. Other metal ions such as Co, Cu, Pb, Zn and Ni and selected mixtures will be considered. Researchers have also initiated the study of the effects of interfering phenomena such as side reactions, poisoning, and preferential removal of concomitant undesired species.

TRANSITION: This projects will transition its result directly DoD and DOE sites, providing a novel and promising technology for efficient waste remediation.

PROJECT SUMMARY

PROJECT TITLE & ID: Negative Ion Sensors for Real-Time Downhole DNAPLs Detection; CU-1089

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Dr. Gregory Gillispie - Dakota Technologies, Inc.

FY 1998 FUNDS: $355K

OBJECTIVE: The objective of this project is to develop a Site Characterization and Analysis Penetrometer System (SCAPS) probe which can detect, locate, quantify, and determine the subsurface distribution of Dense Non-Aqueous Phase Liquids (DNAPLs) in the soil. Location of the DNAPL sources and reliable estimates of their masses are crucial for cost-effective cleanup. No currently available method can accurately and efficiently define the subsurface distribution of chlorinated solvent DNAPLs.

BENEFIT: Using today's technology, the cost to remediate Department of Defense (DoD) sites alone is estimated at $35B. Annual costs >$500K for containment and monitoring a single DNAPL plume are typical. If successful, the sensors developed in this project will provide more cost-effect remediation owing to improved spatial resolution for delineation of DNAPLs source terms, lower sensor acquisition and operating costs, and sensor compatibility with other chemical and physical sensors. Subsidiary benefits include an improved membrane interface for all types of volatile organic compound (VOC) analysis (uphole or downhole) and technology which can be applied to unexploded ordnance (UXO) detection via its chemical signature.

TECHNICAL APPROACH & RISK: The key probe elements are a heated membrane interface and a sensitive, fast-responding downhole detector. Performance objectives have been established as follows: sensor responsiveness to all common organochlorine compounds, vapor limit of detection of 1 ppmv, selectivity better than 5000:1 relative to fuel hydrocarbons, less than 3 second response time, and automatic operation as the probe is advanced by a cone penetrometer or Geoprobe. The research objectives are to characterize the existing Polytetrafluoroethylene (PTFE) membrane's time- and temperature-dependent permeability for chlorinated solvents, fuel hydrocarbons, water, and oxygen; identify, select, and evaluate promising alternative membrane materials; find the material transfer efficiency as a function of distance from the membrane, soil type, temperature, and moisture; and optimize sensor performance, reliability, and ease of operation. Three sensor approaches which exploit the high electronegativity of chlorinated compounds have been identified. They are thermionic ionization sources, a photoemissive electron capture detector (PE-ECD), and a photoemissive ion mobility spectrometer (PE-IMS). The former two will be investigated in this effort. Risk is relatively low because the heated membrane is already in commercial use and preliminary laboratory data have been acquired for the sensors.

ACCOMPLISHMENTS: This is a FY98 New Start.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP) for a full scale demonstration/validation in cooperation with Air Force Center for Environmental Excellence (AFCEE) and Environmental Protection Agency (EPA)-Ada, OK. The researchers also have identified the potential for licencing the sensor technology through a third party.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Geophysical Multi-Sensor Detection of DNAPL Source Zone Identification; CU-1090

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Dr. Jie Zhang - Blackhawk Geometrics, Inc.

FY 1998 FUNDS: $120K

OBJECTIVE: The objective of this project is to provide cost-effective three-dimensional (3-D) geophysical imaging of the geological control on Dense Non-Aqueous Phase Liquid (DNAPL) distribution and migration at different spatial resolutions and, at the highest available resolution, to directly image DNAPL. Specifically, the project plans to develop and implement computer software for performing joint 3-D high resolution seismic and electrical tomography using surface and borehole measurements.

The first year focus is to conduct a proof-of-concept study that includes: 1) developing laboratory data to support Induced Polarization (IP) tomography measurements of low DNAPL concentrations; and 2) conducting a 2-D tomographic image field test.

BENEFIT: The results of this research development will include computer software, downhole seismic, and electrical instruments, and case histories focused on Department of Defense (DoD)/Department of Energy (DOE) sites. The direct benefit of this integrated package is the unique capability to produce high-resolution 3-D images of geological structures and DNAPLs in the subsurface. Collecting field data and conducting 3-D computer tomographic imaging for monitoring DNAPL migration can be completed in real time. When this approach becomes available, it can facilitate the design of new treatment/remediation technologies. Based on the image of DNAPL distribution and its geological controls, it can also help improve risk assessment and estimate the realistic cost for remediation alternatives. Collecting 3-D surface seismic and electrical data may take 2 days. Downhole seismic and direct current (DC) resistivity measurements may take 1 day. Downhole IP measurements need only a few hours. To install a 2-inch temporary well with cone penetrometer takes a few hours and costs only $2K.

TECHNICAL APPROACH & RISK: The project intends to develop a three-fold approach to characterization of physical heterogeneity controlling DNAPL migration and the ultimate imaging of DNAPL distribution in the subsurface: (1) joint 3-D tomographic inversion of surface seismic refraction and electrical resistivity data to broadly delineate subsurface geology; (2) high-resolution joint 2-D/3-D crosshole tomography using downhole seismic and electrical sources and sensors in permanent 4-inch wells and/or temporary 2-inch boring; (3) utilization of the same downhole electrical sensors to perform IP tomography to image DNAPL with the geological constraints from the above two steps. This three-fold

approach will provide new cost-effective, minimally invasive technologies for 3-D geophysical imaging of DNAPL without producing any secondary waste.

ACCOMPLISHMENTS: This is a FY98 New Start.

TRANSITION: Providing a successful initial proof-of-concept study, the project has a transition plan that includes the possible integration with existing systems such as SCAPS to apply the technology developed. Other potential users of the three-dimensional geophysical imaging of DNAPL distribution and migration include: the Air Force Research Lab, Sandia National Lab, and Lawrence Berkeley National Lab.

PROJECT SUMMARY

PROJECT TITLE & ID: Innovative Seismic System for Buried Unexploded Ordnance Detection and Classification; CU-1091

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Mr. Peter Krumhansl - BBN Systems and Technologies

FY 1998 FUNDS: $600K

OBJECTIVE: The objective of this effort is to investigate and develop a new Seismic Ordnance Detection System (SODS), which can improve the discrimination of unexploded ordnance (UXO) from clutter and thus reduce the number of excavations required during cleanup.

BENEFIT: The project intends to provide to SERDP: 1) a fully developed seismic ordnance detection system (SODS) that will significantly improve the accuracy of UXO site characterization and reduce excavations and cleanup costs; 2) a SODS that will provide UXO detection and classification capabilities in environments where other sensors perform poorly; and, 3) a SODS that will detect non-metallic ordnance and other buried wastes or structures.

TECHNICAL APPROACH & RISK: The new seismic sensor will sense the mechanical properties of buried objects rather than their magnetic or electrical properties. The SODS system will operate in a manner similar to an active sonar system, with a mobile seismic array which sends broadband vibrational energy into the ground. These waves when they encounter an object with anomalous mechanical properties cause the object to rotate, translate, and to "ring," scattering energy back to the surface. These echoes will be received by an array of geophones and digitally recorded. The received signals are beamformed to locate the objects and to analyze the characteristic echo from the object. These characteristic echoes when used in conjunction with the magnetic and electrical response will more efficiently differentiate UXO from inert objects. After development and characterization of the performance of SODS, it can be used as one of a suite of sensors that can be tailored to specific site conditions and UXO types. This will significantly reduce survey and cleanup costs, especially in areas with high metal clutter or environmental degradation of the performance of other sensors.

The technical approach for the investigation and development of the SODS consists of three phases: 1) performance of an initial feasibility study to analyze the practicality of seismic UXO detection using short wavelength shear waves; 2) development of a proof-of-concept SODS for testing; and, 3) evaluation of the proof-of-concept SODS in controlled testing. The system simulation of SODS will be based on computer modeling and field measurements of seismic wave propagation and noise. The second phase will utilize seismic sources and receivers that provide greater bandwidth, increased source level, and better earth

coupling than are commercially available while engineering a practical mobile array of seismic transducers that can be used to efficiently collect seismic data. The third phase will include refining of the proof-of-concept system through diagnostic tests and analyzing detections of UXO culminating in an initial evaluation of SODS in multi-sensor tests and an analysis of false alarm reduction using the seismic data in a sensor fusion process.

ACCOMPLISHMENTS: This is a FY98 New Start.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP) to develop a fieldable Seismic Ordnance Detection System prototype.

PROJECT SUMMARY

PROJECT TITLE & ID: Model-Based Data Fusion and Discrimination of UXO in Magnetometry and EM Surveys; CU-1092

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Research Laboratory - Washington, D.C.

PRINCIPAL INVESTIGATOR: Dr. J.R. McDonald

FY 1998 FUNDS: $480K

OBJECTIVE: The objective of this project is the development of data fusion techniques for the best available existing sensor suites, to better allow discrimination between intact ordnance and the typical clutter associated with target and bombing ranges. Specifically, Naval Research Laboratory (NRL) intends to develop software techniques to allow discrimination of intact ordnance from Ordnance Explosive Wastes (OEW) using arrays of full-field magnetometers and time-domain electromagnetic sensors as the primary detection tools. These goals will be accomplished by developing new software for target identification, physical modeling, and probablilistic classification that uses the sensor data sets jointly. NRL's Multi-Sensor Towed Array Detector System (MTADS) will be the primary platform for which the software will be designed, although the work is applicable to any magnetic and electromagnetic array measurements and some aspects of the development are relevant to other types of sensor data.

BENEFIT: When integrated into an operational unexploded ordnance (UXO) survey system such as MTADS, this data analysis system will reduce target analysis time by up to 50 percent. Location information, including position, size and depth, is expected to also be mildly improved. The major benefit of this analysis will be a significantly improved ability to differentiate UXO from OEW and other clutter. An improvement in false alarm levels of a factor of two will reduce ordnance remediation costs by 50 percent at most sites. The probabilistic approach used by the network classifier will provide statistical information that will be important for Quality Assurance/Quality Control (QA/QC) site analysis and for risk-based cost benefit analyses.

TECHNICAL APPROACH & RISK: The key goals of UXO classification and OEW discrimination can best be achieved by a thorough consideration of the fundamental physics of sensors and a development of classification schemes, based on physical understanding, that provide quantitative confidence levels. Therefore, a favored approach is model-based rather than based on raw data. The latter approach performs classification directly from sensor data, whereas this approach performs a joint transform of data to derive physical parameters (position, depth, orientation) allowing the classification to be based primarily on shape information and the intrinsic variables. Initially, raw magnetometry and EM survey data that have been preprocessed (to integrate navigation and sensor data) and mapped onto a two dimensional grid will be automatically processed using principal component analysis to isolate targets with common features in the

multiple data sets. Based upon initial studies with MTADS data from Twentynine Palms and the Badlands Bombing Range, the researchers expect that using this data based approach, 70-90 percent of targets can be automatically selected and analyzed. Following the automatic target selection process, model-based quantitative magnetic and EM routines will be used to solve the inverse problem for target position, depth, shape, and orientation. Then a probabilistic classifier (Bayesian or neural net) will model the output to identify likely UXO type and distinguish OEW or other clutter. Finally, an analyst, (as a backup to the automatic target picker) will work interactively with the individual graphical images, to pick targets which are not common to the magnetometer and EM data sets (or for which the automatic target picker solution was not accepted) for subsequent analysis by the physics-based target fitting routines.

ACCOMPLISHMENTS: This is a FY98 New Start.

TRANSITION: The project has a transition plan that includes: 1) integration of the new analysis system into the MTADS for evaluation; 2) transition of the project to the Environmental Security Technology Certification Program (ESTCP) for demonstration/validation at a live-fire range; and, 3) eventual transition of the current MTADS to the commercial sector.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Clay Formation: A New Technology for Stable Containment Barriers; CU-1093

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Department of Energy

LAB: Sandia National Laboratory - Albuquerque, NM

PRINCIPAL INVESTIGATOR: Dr. J. David Betsill

FY 1998 FUNDS: $270K

OBJECTIVE: A new type of containment barrier with a potentially broader range of environmental stability and longevity could result in significant cost-savings to the Department of Defense (DoD) and Department of Energy (DOE). This project intends to precipitate clays in-situ in porous geologic materials by building on the technologies that exist for colloidal or gel stabilization. Unlike colloidal or gel barriers, however, a precipitated-clay barrier does not require saturated conditions to be functional. Thus, it can be emplaced without loss of performance in the vadose zone as well as areas with fluctuating water tables. Clays have the advantage of being geologically compatible with the near-surface environment and naturally sorptive for a range of contaminants. The precipitation of clays in-situ in soils and sediments should result in (1) reduced permeability and hydraulic conductivity and (2) increased mechanical stability through cementation of soil particles. By analogy with natural diagenesis in sedimentary rocks, the researchers intend to engineer "artificial" lithification in soils and sediments. Unlike natural diagenesis, however, the time-scale for clay growth will be accelerated greatly from more than tens of thousands of years down to a few weeks.

BENEFIT: The results from this project will yield a new barrier technology that potentially has a broader range of mechanical and chemical stability and therefore, can be applied in a broader range of environments ranging from arid to humid, and to specific contaminants, ranging from Dense Non-Aqueous Phase Liquids (DNAPLs) to metals. DoD and DOE cleanup sites are located in a wide range of environments across the country and have a range of contaminants. The new barrier technology should also possess greater longevity requiring less maintenance over the longterm and less risk of remediation due to barrier failure or leakage. Total cleanup costs to the DoD and DOE should be substantially reduced due to the longer lifetime of the barrier. Once developed, it is anticipated that the implementation cost of the new barrier technology should be on the order of the least expensive chemical grouting technologies currently available.

TECHNICAL APPROACH & RISK: The technical approach is multidisciplinary and involves plans to: (1) confirm published results suggesting that clays can be precipitated in a few weeks to months from aqueous gels; (2) design an optimal gel composition that will maximize clay yield and crystallization rate, while maintaining injectability into porous soils and sediments; (3) test the barrier formulation in laboratory

experiments; and, (4) test the method in a field experiment. The critical key step in developing the new barrier technology will be to successfully optimize the formation of clays from aqueous gels under ambient conditions. Therefore the first year of the project will be focused on this step. However, we will also initiate the laboratory experiments and measurements (flow properties and mechanical stability) in order to address technical details that may arise with the materials or experimental design. Gel composition will be designed using approaches taken from the literature involving reactions and additives known to accelerate clay formation. Emphasis will be placed on characterizing the clay with respect to quantity, composition, and crystallinity. Emplacement of gels in laboratory tests will emulate field technologies such as permeation and jet grouting, and soil-mixing.

ACCOMPLISHMENTS: This is a FY98 New Start.

TRANSITION: The project has a transition plan that includes: 1) full-scale demonstration of the clay formation technology at a DoD site; 2) pursuit of cooperation with industry and consortia (i.e., Remediation Technologies Development Forum); and 3) direct sharing of information on methodology to DoD and DOE installation managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmental Impacts to the Chemical Signature Emanating from Buried UXO; CU-1094

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Department of Energy

LAB: Sandia National Laboratory - Albuquerque, NM

PRINCIPAL INVESTIGATOR: Mr. James Phelan

FY 1998 FUNDS: $200K

OBJECTIVE: The objective of this project is to develop a validated subsurface transport model that can be used to predict the spatial and phase specific concentration of chemical signature molecules derived from shallow unexploded ordnance (UXO) under the influence of specific environmental conditions. Other government programs are developing chemical detector platforms that can provide a separate unique signal to classify subsurface objects identified with existing geophysical systems. It is estimated that eleven million acres of land needs assessment to identify subsurface UXO - with costs estimated to be about $1.4M/acre. The ranges where UXO can be found is distributed throughout the country where environmental conditions vary significantly. It is the hypothesis of this project that these environmental conditions will have a significant impact on the transport of chemical signature molecules from subsurface UXO to the surface before presentation to a chemical detector system. If through this systems analysis, one can show the ranges and/or combinations of environmental parameters that improve the transport of chemical signature molecules to the chemical detector system, and conversely, those that constrain this movement, end-users seeking to will be better positioned to understand the merits and limitations when looking to deploy the chemical detector technology.

BENEFIT: This project will provide Department of Defense (DoD) with a new tool to assess the functionality of chemical detector platforms in service to classify shallow UXO from non-UXO. Use of the model, simulations, and systems analysis will improve the decisions made on the utility of chemical detector platforms in a variety of environmental conditions that are expected to have an important role in the transport of chemical signature molecules from shallow UXO. If chemical detector platforms can meet the performance requirements for many application sites, a substantial savings can be expected in reducing the number of non-UXO items treated as UXO during range cleanup activities.

TECHNICAL APPROACH & RISK: The first task is to perform a sensitivity analysis of known input parameters in a one-dimensional analytical contaminant transport model, expand this model to assess two-dimensions to explore the surface area footprint from buried UXO, modify an existing numerical simulation code (T2VOC) (precipitation/evaporation, temperature cycling, liquid diffusion) for use as the complete systems analysis tool. Inverse modeling will be used to assess input parameter sensitivity and as a tool for the design of laboratory validation experiments in task three. Task two involves the measurement

of specific transport parameters currently not available in the literature for explosive signature molecules. These include temperature dependent water solubility, vapor-solid sorption as a function of soil moisture content and source-term emission rates. Task three will be a laboratory validation study that will confirm the most critical parameters included in the simulation model. Task four will utilize this validated model to assess the impacts of environmental conditions on the transport of chemical signature molecules from shallow UXO and support end-user queries on the utility of chemical sensor platforms for the classification stage in the identification of true unexploded ordnance.

ACCOMPLISHMENTS: This is a FY98 New Start.

TRANSITION: The project has a transition plan that includes: 1) sharing of Performance Targets directly with developers of commercial chemical detector systems; 2) making available operational strategy information to end-users; and, 3) pursuing advancement of the chemical detector platform through a demonstration/validation field testing program, such as the Environmental Security Technology Certification Program (ESTCP) or the U.S. Army Night Vision Lab.

PROJECT SUMMARY

PROJECT TITLE & ID: Assessment and Prediction of Biostabilization of Polycyclic Aromatic Hydrocarbons (PAHs) in Sediments; CU-1095

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Mr. Jeffrey W. Talley

FY 1998 FUNDS: $500K

OBJECTIVE: The objectives of this research are to identify those factors affecting biostablization of Polycyclic Aromatic Hydrocarbons (PAHs) in sediments and to develop the technical basis for enhancing natural recovery processes for the biotreatment of PAHs in dredged material. The key questions to be addressed in this research are: (1) Where exactly at the microscopic scale do PAHs reside on aged sediments?; (2) How are the microscopic-scale locations of PAHs on sediments dependent on sorbent carbon location and type?; (3) What are the distribution of binding activation energies for desorption of PAHs from sediment particles, and how does this correlate with information on PAH association with sorbent carbon type?; (4) How does the effectiveness of bioslurry treatment of dredged sediments depend on the locations and associations of PAHs with sorbent organic matter and distributions of binding activation energies with respect to removal of specific compounds, the fraction of labile and resistant PAHs, and the toxicity of residual PAHs?; and (5) How may knowledge of the association of PAHs with sorbent carbon type and location, and distribution of binding activation energies, be used to assess and predict the overall performance of bioslurry processes for biostablization of PAHs? This research will assess the fundamental character of the binding of PAHs at the microscopic scale in parallel with bioslurry treatment and ecotoxicological testing, to show how the nature of PAH association with sediments related to biostablization, achievable treatment endpoints, toxicity, and bioavailability. The work will explore mechanisms controlling PAH sequestration using novel spectroscopic techniques to examine at the microscale the distributions and associations, and binding energies of PAHs in sediments.

BENEFIT: The potential benefits of this research include: reduced treatment costs, improved evaluation and design for clean-up technologies, greater regulatory and public acceptance of biostablization, increase in the reuse/recovery opportunities for treated contaminated dredged materials, and potential application for in-capped sediments.

TECHNICAL APPROACH & RISK: The project's overall goal is to develop micro-scale characterization of PAH homolog distributions in sediment, and to use this information to provide more direct evidence of PAH associations with geosorbents for the construction of mechanistically-based conceptual models to aid interpretation of bioslurry treatment efficiency and toxicity of treated and untreated material. The novel aspect of this research is the use of unique, complementary spectroscopic

techniques to assess where and how PAHs are bound to sediments. The technical approach for the first year is: 1) investigate the utility of microprobe two-step laser desorption/laser ionization mass spectrometry uL2MS, for direct observation of PAHs on aged laboratory and field soil/sediment particles at the microscopic scale, i.e., 40 um or less; 2) employ the uL2MS method to examine lateral and criss sectional variations of PAH homolog distributions on sediments; 3) compare the surface and sectional amounts of PAH homologs obtained by uL2MS with results from conventional whole sample extraction and Gas Chromatography/Mass Spectrometry (GC/MS) or Gas Chromatography/Free Induction Decay (GC/FID) analyses; and, 4) determine the distribution of microorganisms on sediment particles, and the competence of these organisms to degrade PAHs.

ACCOMPLISHMENTS: This is a FY98 New Start.

TRANSITION: The project has a transition plan that includes dissemination of results through established scientific communications channels, as well as proposed partnering efforts with the Army Research Office and the Gas Research Institute.

APPENDIX B
Compliance Project Summaries

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PROJECT SUMMARY

PROJECT TITLE & ID: Compact, Closed-Loop Controlled Waste Incinerator; CP-34

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center - China Lake, CA

PRINCIPAL INVESTIGATOR: Dr. Klaus Schadow

FY 1998 FUNDS: $500K

OBJECTIVE: This project will establish the Science and Technology (S&T) basis for a compact, closed-loop-controlled waste incinerator using resonant acoustics for enhanced waste pyrolysis and controlled vortex dynamics for enhanced and controlled after burning. The after burning process will be closed-loop controlled using newly developed control components, including diode-laser based sensors for real-time and continuous emission monitoring, new types of actuators, and a non-standard controller based on fuzzy logic or neural nets. A second SERDP project, **CP-887 Demonstration of a Compact, Closed Loop Controlled Waste Incinerator,** is applying this new technology to two Navy incinerator programs (see Project Summary for CP-887 in this Appendix).

BENEFIT: Successful demonstration of a compact incinerator with real-time exhaust monitoring for active combustion control represents a significant step towards assured waste incineration and can be the basis for the next-generation incinerators. The compact-incinerator technology will be demonstrated for specific shipboard application and will be essential for the development of environmentally sound ships beyond the year 2000. Compact incinerators also are desirable for on-shore use in the government and private sector. Small, compact incinerators will allow on-site waste destruction and avoid waste transportation to large incineration sites. In particular, medical waste incineration is a prime candidate in the private sector for a compact incinerator system. The closed-loop active control of the incineration process will, for the first time, assure proper incineration. Assured waste incineration on-board ships will result in significant cost savings by avoiding costs for waste off-loading and on-shore destruction, particularly in foreign countries.

TECHNICAL APPROACH AND RISKS: The S&T studies consist of: (1) control component development which includes separate tasks for the development of advanced sensors, actuators, a process model, and an adaptive controller; and (2) sub-scale evaluation and integration. Sub-scale experiments with advanced laser diagnostics are being conducted to evaluate both the trapped-vortex and periodic-vortex concepts, validate control components, and integrate control components. The effectiveness of the new closed-loop controlled system will be compared to existing incinerator technologies in terms of compactness and emission characteristics. These sub-scale integration tests will further define the requirements and design criteria for full-scale demonstration and optimization of the sludge incinerator and the plasma arc afterburner in SERDP project **CP-887**.

ACCOMPLISHMENTS: In FY 1997, this project focused on two areas: improvement of the afterburner using active combustion control and improvement of the sludge incinerator using resonant acoustics. For the actively controlled afterburner, progress has been made in four areas: (1) the afterburner was re-designed for extended duration with hot pyrolysis gases, (2) data acquisition and analysis hardware for the diode laser sensor system were improved, (3) the fuzzy controller was adapted to the current afterburner geometry and unsteady pyrolysis gas mass flow, and (4) failure modes were determined for incineration in actively established vortices. Additional accomplishments included: the feasibility of using diode laser based sensors under practical operational conditions was demonstrated; closed-looped active combustion control was achieved; and the 1-dimensional engineering model was applied to the afterburner. Good agreement for NOx and CO between experiments and predictions was obtained. The engineering model will be used for optimization studies of the afterburner.

TRANSITION: Continuing interaction is taking place with the Navy for: multi-functional incinerators (for sludge and oil); demonstrating acoustics retrofits; developing an afterburner for another Department of Defense (DoD) facility under a joint development program. Three marine incinerator manufactures with an interest in collaboration have been identified and a proposal for collaboration with one has been developed. The Principal Investigator is pursuing future DoD funding for a compact, integrated system for hazardous waste incineration at DoD facilities and for 6.4 research funding for shipboard advanced incineration.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduction of NOx Emissions from Marine Power Plants; CP-42

RESEARCH CATEGORY: 6.4 Demonstration and Validation

LEAD AGENCY: U.S. Navy

LAB: Naval Surface Warfare Center - Annapolis, MD

PRINCIPAL INVESTIGATOR: Dr. Herman Urbach

FY 1998 FUNDS: $500K

OBJECTIVE: The Navy has been directed to make a good-faith attempt to comply with anticipated, state-imposed limits on emissions from a naval inventory of about 700 gas turbines and 2,700 diesel engines on ships operating within coastal waters. One low-risk, low-cost, state-of-the-art development achieves low-NOx emission from gas turbines by injecting water into the gas-turbine combustor. For diesel engines, simultaneous use of injection timing retardation, exhaust-gas recirculation, and water injection appear necessary to achieve anticipated state-imposed emission standards. The impact of these emission-reducing technologies on complicated ship engines, including their ability to operate without unscheduled loss of power in a tactical situation may be assessed only through realistic shipboard evaluation. It is the objective of this project to establish within the Navy community, the credibility of these technologies as an acceptable method of reducing NOx emissions from Navy engines in a naval, at-sea operating scenario.

BENEFIT: This project will allow the Navy to operate as an ecologically benign neighbor in domestic and global maritime environments. It will permit the Navy to avoid litigation and to operate in zones subject to strict limitations of NOx emissions, such as the California littoral and congested European ports.

TECHNICAL APPROACH AND RISKS: A water-injection controller (WIC), designed and fabricated for injection of water into the combustor of an LM2500 gas turbine will be tested at the LM2500 test and land-based simulation facility at a Naval facility in Philadelphia. Pending successful resolution of these tests, and management concurrence, the WIC system will be installed on an FFG-Class ship at the Norfolk shipyard. After ship integration, the WIC system and its automated emissions monitor will undergo at-sea testing to assess the overall impact of the WIC system on the gas-turbine plant and ambient ship systems.

A DDC 4-71 diesel engine will be modified to retard the timing of fuel injection, to introduce exhaust gas recirculation, and to inject water in the form of an emulsified, fuel-water mixture. The manually-controlled system will be tested at research facilities of the North Carolina State University prior to any testing in a Yard Patrol (YP) ship at Annapolis. Studies will assess the risks of erosion/corrosion in the fuel injectors, flame quenching, and/or cylinder misfiring. The at-sea test in the YP will assess all ship-system impacts.

ACCOMPLISHMENTS: In FY 1997, tests of the performance of the WIC system indicated that too much water quenched the flame near idle, when both the flame temperature and flame stability are low.

As a result, the software program was modified to reduce water injection when the engine approaches the idle condition. Also, the water manifold will be modified to reduce undesirable flow fluctuations, which generate oscillation in both the water and fuel manifolds.

Tests also showed that two-stroke, turbocharged, marine diesel configurations combining exhaust-gas recirculation, retardation of injection timing, intercooling, and an oxidation catalyst for the combustion of volatile organic compounds and particulates lower NOx-emission levels to below Environmental Protection Agency (EPA) mandates. In addition, the new system reduces carbon monoxide and particulate matter below mandated levels without loss of rated power.

Water-injection into the combustor of the LM2500 engine reduces the NOx emissions to the planned objective level of 42 ppm during steady-state engine operations at all levels of throttle output power. Particulate-emission tests on the diesel engine were completed at 96 percent load levels. The measurements averaged 0.25 g/kWh (less than half the proposed EPA standard of 0.54 g/kWh) with NOx levels below 9.0 g/kWh. These tests completed the NOx control evaluation at constant speed (1800 rpm) in mid April.

TRANSITION: A paper entitled "The Reduction of NOx Emissions from Marine Power Plants" was presented before the Air & Waste Management Association's 90th Annual Meeting held June 8-13 in Toronto. An at-sea shipboard test will be conducted with a Yard Patrol boat at Annapolis will be retrofitted with emission-reducing hardware to demonstrate reductions of NOx emissions below the mandated limit.

PROJECT SUMMARY

PROJECT TITLE & ID: Emission Reduction Planning Model; CP-175

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Major Carolyn Vadnais

FY 1997 COMPLETED PROJECT

OBJECTIVE: This project developed an Emission Reduction Planning Model (EPRM), an integrated emissions-dispersion database and expert decision system to aid environmental planners and air pollution managers in reducing criteria and hazardous air pollutant emissions at Air Force and Army installations. Complying with, and moving beyond, the requirements of the 1990 Clean Air Act Amendments and evolving Federal/state/local regulatory standards will be very difficult with the current myriad of non-standardized approaches. A system combining air quality impact assessment with rule-based algorithms for determining optimal reduction and control strategies will enable the Air Force and Army to apply cost-effective control and mitigation techniques in a consistent manner.

BENEFIT: A system combining air quality impact assessment with rule-based expert algorithms for determining optimized reduction and compliance strategies will enable the Air Force and Army to apply cost-effective control and mitigation techniques in a consistent manner. Man-hours and expense involved in selecting and implementing high-impact emissions reduction programs will be reduced as a result. The resulting software may have substantial application potential at other Federal and private facilities.

ACCOMPLISHMENTS: In FY 1997, the data structure and the algorithms for automatically matching alternative compliance strategies (e.g., pollution prevention alternatives, improved management practices suggestions) have been completed. The alternative compliance strategy database was updated. Phase II of the field testing was officially completed in the first quarter of this year. Additional beta test versions of the ERPM/Air Compliance Advisor (ACA) were released to potential end users as improvements are made. The fifth beta test version of the ACA software (beta version 5.4) was completed and made available on the U.S. Environmental Protection Agency's (EPA) Control Technology Center (CTC) bulletin board. The software is also available on a world wide web (WWW) homepage at: http://quattro.me.uiuc.edu/~acad/. An article on this project (including comments by Defense Environmental Security Corporate Information Management (DESCIM) personnel) appeared in the July issue of *Pollution Engineering*.

TRANSITION: The ERPM software appears to provide much of the initial capability required by the DESCIM-Program Management Officer and could be expanded to provide most of the other necessary functions. Acceptance of the ERPM as part of the DESCIM software package would ensure a broad user

community (throughout the Department of Defense) as well as providing for long-term maintenance and upgrades to the software. The Principal Investigator plans to work closely with the DESCIM-PMO over the next few months to pursue this transition. The ERPM can also function a stand-alone program; therefore, the PIs are working with staff at the AFCEE to transition the software. AFCEE has agreed to distribute and support the software out of the AFCEE office at Brooks Air Force Base, TX.

PROJECT SUMMARY

PROJECT TITLE & ID: Metal Perovskite Catalysts for NOx Reduction; CP-177

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Dr. Joseph Wander

FY 1997 COMPLETED PROJECT

OBJECTIVE: The overall objective of this project was to investigate the use of a strontium-lanthanum cobaltate catalyst for reduction of oxides of nitrogen (NOx) in high-temperature environments such as high-performance jet engines and exhaust manifolds of diesel or gasoline engines. The thermodynamics and kinetics of reduction of strontium-lanthanum cobaltate in NOx and the limits of stability of the active, oxygen-deficient phase will be determined to establish its long-term effectiveness as a catalyst for reduction of NOx.

BENEFIT: The benefit derived from this research will be the determination of the feasibility and economics of using strontium-lanthanum cobaltate catalysts for reduction of NOx in high-temperature environments. The advantage of using this transition metal as a catalyst is a significant cost savings over noble metals such as platinum. Technology can be transitioned to private sector industries such as aviation and internal combustion engine manufacturers. This supports the SERDP research and development objective of developing treatment technologies for installation support operations.

ACCOMPLISHMENTS: In FY 1997, the design for the high space velocity reactor was completed. The system uses strontium-lanthanum cobaltate plasma coated on stabilized zirconia tubes. Construction and testing of the annular flow apparatus continued. The integrity of the system (with respect to gas leaks) was confirmed for room temperature up to the upper test temperature of 1300°C. Simulation and modeling of the high temperature gas reactions was conducted to determine the simulated exhaust gas compositions to be used in the reactor for testing stoichiometric and non-stoichiometric burn conditions. The research team received a 1997 R&D 100 Award from *R&D Magazine* for the NOx and particulate filter technology.

TRANSITION: The results of this 6.2 basic research will be used in a follow-on 6.3 technology demonstration effort of catalyst performance in controlling emissions from an operational combustor at an Air Force facility. Favorable results will allow technology transfer to the Turbine Propulsion Office of the Air Force Research Laboratory.

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced Mass Spectrometry for Atmospheric Monitoring; CP-192

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Kirkland Air Force Base, NM

PRINCIPAL INVESTIGATOR: Dr. John O. Ballenthin

FY 1998 FUNDS: $600K

OBJECTIVE: This applied research effort is developing and demonstrating technology to measure the concentrations of trace gas-phase neutral species in the stratosphere, troposphere, and ground level atmosphere. This technique is broadly applicable to the SERDP Compliance pillar by providing an effective, robust, portable apparatus capable of detecting major and minor pollutants with greater than a trillion-to-one dynamic range and part-per-quadrillion sensitivity.

BENEFIT: This research program will lead to high sensitivity measurements of the concentrations of many chemical species at ground level and in the troposphere and stratosphere. Models of the chemistry of polluted environments can then be improved by adjusting the model to match the measurements. The validated models can then be applied with confidence to environmental scenarios where direct measurements have not been made. An immediate benefit of the research will be to ensure compliance of jet- or rocket-engine emission with mandated standards and to support Department of Defense (DoD) efforts to reduce pollution from jet and rocket operations. The end-product of the research will be a portable, highly-sensitive, calibrated, and tested instrument that will be suitable for commercialization and use by the environmental monitoring community.

TECHNICAL APPROACH AND RISKS: This effort is capitalizing on the chemical reactions between neutral pollutant gas molecules and naturally present, atmospheric ions which often produce new ion species that are unique signatures of the original trace neutral. Because of the very small background signal level for ions, the technique routinely provides sensitivities to detect neutrals in the parts-per-quadrillion levels. Risks have been minimized since the concept has been developed and proven by laboratory measurements. The prototype mass spectrometer has already been demonstrated to function in upper tropospheric and lower stratospheric measurements of jet engine exhaust composition. The critical path to program completion will be: develop and demonstrate the capability of a portable system for jet, rocket and other plume measurements with comparisons with competing instrumentation; demonstrate the capability of the system for analysis of complex pollutant mixtures present in such sources as jet engines test cells and stack processes; and perform laboratory measurements of trace neutral ion chemistry of relevant species.

ACCOMPLISHMENTS: In FY 1997, a letter was signed with Aerodyne Corporation to apply the

Advanced Mass Spectrometry Instrumentation to an in-situ measurement program utilizing remotely piloted vehicles to make long duration measurement of Navy stack plumes. A paper publishing the measurements of the dependence of rate constants of SO_2 with hydrated CO_3 core ions is in press at Geophysics Research Letters. The paper shows the applicability of this measurement technique even under wet atmospheric conditions--an important result in application of the technology to real world conditions. The laboratory high pressure turbulent flow tube is now coming on-line. This facility permits measurement of relevant rate constants with direct laboratory simulation of real world pressures.

Important advances were made in the mass spectrometry system. These improvements extend the dynamic range of the instrument by two orders of magnitude with only a minimal loss in absolute sensitivity. This tradeoff is expected to be beneficial for measuring undiluted stack exhaust gases.

Near field exhaust plumes of F-16 aircraft using three fuels with high, medium, and low sulfur content were measured. The advanced mass spectrometry instrumentation was installed on a National Aeronautics and Space Administration (NASA) T-39 research aircraft which intercepted the exhaust plumes of the F-16s. Plume composition was charted at altitudes of 30,000 and 40,000 feet and at F-16 power settings between 60 percent and 90 percent. The data quality was exceptionally good; the high sensitivity and fast time response of the mass spectrometer system permitted observation of plume structure with time resolution down to 0.01 to 0.1 seconds for the part per billion level measurements. Dramatic differences in plume composition as a function of fuel sulfur content were observed. These measurements will improve models of the effect of fuel sulfur on gaseous emissions of jet aircraft, which in turn will aid in understanding contrail formation mechanisms and aerosol production mechanisms.

An F100 engine (used by Air Force F16s) was operated under test conditions of idle to military power at simulated altitudes of 10,000 to 55,000 feet. A variety of fuel formulations was tested, ranging from low to high sulfur content as well as a common military formulation. The exhaust gas from the engine was sampled within 12 inches of the engine exit plane. The advanced mass spectrometer system was configured to provide high sensitivity measurements of the various sulfur species in the exhaust. Good measurements of SO_2 were obtained for all fuel, engine, and altitude conditions. Measurements of nitric acid emissions were also obtained. The measurement system included a calibration system designed to provide absolute abundances of the SO_2 and HNO_3 measurements and also to determine the effect of the long sample tube upon these gases. These measurements will improve models of the effect of fuel sulfur on gaseous emissions of jet aircraft, which in turn will aid in understanding contrail formation mechanisms and aerosol production mechanisms. Two papers were published in Geophysics Research Letters and seminars were given at the University of Waterloo, York University and RPI Troy.

TRANSITION: Potential users of this technology include: Air Force Research Laboratory - fire suppressant studies and jet engine emission estimates; NASA - measurements are required for the subsonic aircraft program; the Titan program - emissions measurements; and real-time multiple species monitoring for commercial environmental monitoring. The technology is directly applicable to mass spectrometric instrumentation companies and preliminary discussions with a potential Cooperative Research and Development Agreement partner have commenced.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Open Burning/Open Detonation (OB/OD) Emissions; CP-247

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Dugway Proving Ground - Dugway, UT

PRINCIPAL INVESTIGATOR: Mr. R. J. Black

FY 1997 COMPLETED PROJECT

OBJECTIVE: This project is part of a program to develop a testing system fully capable of characterizing emissions produced by the open burning/open detonation (OB/OD) of all conventional munitions and energetics within the demilitarization system. This characterization will make the OB/OD disposal process more efficient, reduce the impact of OB/OD operations on the environment, and facilitate the OB/OD permitting process. Computer-simulated emissions data have not been accepted by regulators, requiring that actual OB/OD test emissions data be submitted for Subpart X permits.

BENEFIT: The optimization of the OB/OD treatment process, which is fast, inexpensive, and safe, will provide a scientifically sound method for minimizing toxic emissions and sound and pressure waves generated by open-air OB/OD thermal treatment. By providing both the technologies to accurately generate OB/OD emissions and data that can justify continuation of OB/OD operations where appropriate, this project is averting crises of major proportions and will also produce significant cost savings in munitions and Propellants, Explosives, Pyrotechnics (PEP) disposal. As items suitable for OB/OD disposal are identified, those items unacceptable for OB/OD treatment will likewise be identified, allowing for the focusing of Research and Development (R&D) funds for alternate disposal technologies where the need is greatest.

ACCOMPLISHMENTS: In FY 1997, the Phase II OB/OD facility, referred to as ODOBi, was constructed and delivered to and installed at Dugway Proving Ground (DPG). A sampling equipment bunker for the ODOBi research facility was constructed. Training and testing for the ODOBi were completed. In addition, emissions data from early (pre-1995) OB/OD tests are being added to the emissions characterization database. A comprehensive examination of the emissions database was conducted in order to identify which target analytes provide the highest probability of determining if emissions can be used to classify munitions and, therefore, which should be priority analytes in future tests. Statistical analyses on the results of munitions and PEP tests were performed to order to classify emissions into families. Finally, the 10-item test report (Characterization of Emissions Produced by the Open Detonation Thermal Treatment of Ten Selected Munitions) has been completed. Emissions factors from the emissions database have been forwarded for incorporation into the Munitions Items Disposal Action System database.

TRANSITION: The BangBox emissions factor data was accepted by Environmental Protection Agency/ Office of Solid Wastes, all EPA Regions, and several states. Joint testing programs have been established with other agencies, including the Air Combat Command, U.S. Army Construction Engineering Research Laboratory, and private industry. Project results are continually being presented in the open literature. Field validation studies are being conducted at active Demil Sites (e.g., Danvers, IL). Engineering models, design specifications, and operations manuals are being released to Demil sites at which OB/OD facilities can be constructed.

PROJECT SUMMARY

PROJECT TITLE & ID: Leak Location in Underground Pipelines; CP-249

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Environmental Protection Agency

LAB: National Risk Management Research Lab - Edison, NJ

PRINCIPAL INVESTIGATOR: Mr. Anthony Tafuri

FY 1997 COMPLETED PROJECT

OBJECTIVE: The project objective was to develop and demonstrate a non-invasive and non-destructive system for detecting and locating small leaks in pressurized pipelines. The technology must be accurate, simple to use, and applicable to a wide variety of pipelines and products. This technology will be utilized to detect and locate small leaks from the thousands of miles of Department of Defense (DoD) and Department of Energy (DOE) pressurized pipelines worldwide.

BENEFIT: This project benefits DoD and DOE by providing technology to assure rapid compliance with regulatory requirements. The ability to quickly locate leaks in critical pipelines insures a state of readiness on the part of DoD facilities to fulfill their missions. For example, a forced shutdown of fuel handling operations due to leaks would immobilize military equipment and delay transport of military personnel and equipment. The timely detection and location of leaks will reduce the costs of environmental cleanups, mitigate legal liabilities due to damages, and maintain good community relations.

ACCOMPLISHMENTS: In FY 1997, project work indicated that acoustic sensors work more effectively when there is a close association of the active sensor face with the metal surface of the pipe. This means that coatings between the pipe surface and the sensor will present difficulties. These can be overcome for new construction with permanent attachment of sensors prior to coating of the pipe. For many existing applications, the pipe surface can be assessed at non-coated locations, such as manholes or fitting connections. For field situations where the coating must be removed, field practices now used to reapply the coatings need to be identified. In terms of the technology itself there is a question of the effect of any outer wall coating on the attenuation of the signal as it passes down the pipeline. Discussions with the Naval Research Laboratory have taken place with regard to incorporating their expertise in the signal analysis area to define the theoretical limits of applicability of the acoustic techniques to this type of problem.

TRANSITION: Project results have been presented as Agency technical papers and reports, refereed journal articles, and papers presented at conference and symposia.

PROJECT SUMMARY

PROJECT TITLE & ID: Measuring and Modeling for OB/OD Permitting; CP-251

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Environmental Protection Agency

LAB: National Risk Management Research Laboratory - Research Triangle Park, NC

PRINCIPAL INVESTIGATOR: Dr. William J. Mitchell

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective of this project was to develop a mobile meteorological observation platform and air pollution dispersion model which can be used to predict the impact of open burning and open detonation (OB/OD) of demilitarized munitions on human health and surrounding ecosystems. The observation and modeling techniques developed in this project will help to significantly reduce the demilitarized stock pile in a timely, cost-efficient manner that is environmentally safe.

BENEFIT: This project provides Department of Defense and Department of Energy tools to acquire the information needed to obtain a RCRA Subpart X permit for OB/OD activities. Use of the Mobile Meteorological Observation Platform and OB/OD transport and dispersion model helps to reduce the demilitarized stockpile in a timely, cost-efficient manner that is environmentally safe. OB/OD activities are generally less expensive than other reclamation and/or disposal methods; therefore, a substantial savings in cost should also be realized.

ACCOMPLISHMENTS: In FY 1997, the mobile meteorological measurement system (MMMS) was incorporated and validated in the Denver Brown Cloud study and MMMS refinements were completed. The MMMS was subject to a Quality Assurance/Quality Control review and the mixed-layer height algorithms were installed and validated. For the dispersion model, accomplishments included: development of meteorological preprocessor algorithms; completion of alogrithms for thermal rise, dispersion, deposition, and terrain; completion of thermal rise and dispersion experiments; and completion of the model algorithms in the OB/OD code.

TRANSITION: Project results are being presented to potential users via refereed journal articles, symposia, and technical reports. User guides, design specifications, and performance characteristics of dispersion model and MMMS were released in interim and final forms during the project. The dispersion model was made available through the Environmental Protection Agency (EPA) regulatory support electronic bulletin board located at: http://www.epa.gov./scram001. A proposal was submitted to the Environmental Security Technology Certification Program (Dem-Val) for FY98 funding to field test combined products from SERDP project CP-247 and this project.

PROJECT SUMMARY

PROJECT TITLE & ID: Vapor Permeation VOC Recovery from Refueling and Storage Operations; CP-252

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Environmental Protection Agency

LAB: National Risk Management Research Laboratory - Cincinnati, OH

PRINCIPAL INVESTIGATOR: Dr. Subhas Sikdar

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective of this project was to develop a cost-effective technology suitable for preventing the loss of fuel hydrocarbon components to the atmosphere during fuel transfer operations, refueling operations, and fuel storage. Volatile Organic Compounds (VOCs) in air can be recovered by simple condensation. However, if the concentration of VOCs in the air is dilute, as is the case when VOCs are lost to air during filling a tanker or storage tank, direct condensation would not be economical because of the large air volume involved. Thin-film, non-porous membranes specially made of a hydrophobic resin are capable of recovering VOCs from fuels for direct recycle/reuse. In the vapor permeation process, the VOCs are removed from the VOC-air mixture and condensed back to a liquid phase with very high selectivity. A vacuum is applied and the VOCs are recovered in a condenser. An inert gas sweep also can be used in place of vacuum to achieve similar, and in some cases, superior results.

BENEFIT: Successful development of this technology will provide a cost-effective approach to eliminate a source of hydrocarbon emissions to the atmosphere reducing photochemical smog formation, ozone formation, and evaporation fuel losses during fuel handling and storage. It is anticipated that fuel loss avoidance will more than pay for the total costs, including energy penalty costs, of other control techniques, which would be required to control emissions in areas requiring such controls, particularly California. Extensive implementation of this technology in the civilian sector could alleviate existing pollution levels sufficiently to provide offsets to the military operations.

ACCOMPLISHMENTS: In FY 1997, the Naval Facilities Engineering Services Command completed a review of fuel types used in the military and a review and inventory of VOC emission sources at military installations. The bench-scale research for the control of fuel vapor emissions was completed in November 1996.

TRANSITION: Four technical papers were published in peer-reviewed journals and presentations were made at the Northeast Hazardous Substance Research Center, and the National Risk Management Research Laboratory's Annual Research Symposium.

PROJECT SUMMARY

PROJECT TITLE & ID: Laser Ablation/Ionization Characterization of Solids; CP-362

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Pacific Northwest Laboratory - Richland, WA

PRINCIPAL INVESTIGATOR: Dr. Steven D. Colson

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective of this project was to develop general and sensitive techniques for determining the molecular speciation of organics and inorganics in tank wastes and those chemisorbed on mineral soil substrates. These methods must be sensitive to a broad spectrum of compounds to detect the many species present in mixed waste environments. Development of multiphoton-ionization techniques is required to satisfy the critical need for sensitive and rapid detection of technetium-99 and strontium-90. Compared to current methods which require weeks, laser analysis can be completed in hours.

BENEFIT: This technology will increase the capabilities to analyze mixed waste. The results will be useful in performing the analysis of tank waste and crib wastes as well as contaminated soils and groundwater. The near-real-time analysis capabilities of these methods will also be important for monitoring waste retrieval, facilities decontamination, and other site restoration actions. It will contribute to the success of the Department of Energy (DOE)/Hanford Mobile Analytical Reconnaissance System program which constitutes a major effort in meeting Hanford-site remote analytical and characterization needs for hot cells, and is predicted to result in a savings of $30-75 million during the three years following its implementation. Similar percentage savings can be expected at other Department of Defense (DoD) and DOE sites.

ACCOMPLISHMENTS: Sensitive molecular speciation of waste compounds has been demonstrated using matrix assisted laser desorption ionization (MALDI) mass spectrometry techniques. The calibration of ablation yield of waste compounds, oxalic and citric acids, and sulfate was completed by October 1996. Complete analyses of waste stimulants using negative ion detection were completed in August 1997.

TRANSITION: The project team is pursuing funding to transition Laser Ablation/Ionization Characterization of Solids technology to staff at the Los Alamos National Laboratory in the Plutonium Focus Area. There is a potential use for Laser Ablation/Ionization Characterization of Solids technology in soil analysis of shooting ranges; therefore, contact with the Industrial Operations Division of the U.S. Army Construction Engineering Research Laboratory has been initiated. The purpose of this contact is to disseminate results of the Laser Ablation/Ionization Characterization of Solids program to possible DoD end users.

PROJECT SUMMARY

PROJECT TITLE & ID: Kinetics of Supercritical Water Oxidation; CP-364

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: Department of Energy

LAB: Sandia National Laboratory - Livermore, CA

PRINCIPAL INVESTIGATOR: Dr. Steven F. Rice

FY 1998 FUNDS: $300K

OBJECTIVE: Supercritical water oxidation (SCWO) is a technology under development by government laboratories, universities, and private industry for the treatment of aqueous wastes. However, the current understanding of the rates and mechanisms of reactions in supercritical water is limited to a handful of empirical rate expressions for very simple chemicals. These expressions are of limited use in the formulation of predictive models of SCWO for the design and operation of large-scale waste processing equipment. To be generally applicable as design tools, models must be based on elementary reaction steps or, at minimum, a detailed quantitative mechanistic description incorporating all the key fundamental reactions. This is a basic research project that will improve our ability to predict reaction rates in supercritical water. The project is designed to result in a user-friendly, computer-based model that will predict reaction rates and conversion efficiency for a wide range of waste feeds and reactor conditions.

BENEFIT: SCWO is an emerging technology under development at several laboratories, including Sandia National Laboratory, for the treatment of hazardous wastes such as obsolete chemical munitions, mixed wastes, and naval shipboard excess hazardous materials. The SCWO process, operating at two orders of magnitude greater density than atmospheric gaseous combustion, provides high reaction rates at moderate temperatures. The technical chemical engineering literature contains results of studies of SCWO measuring destruction efficiencies for a variety of waste chemicals and mixtures. Some of this data can be used to generate empirical, global kinetic rate expressions for a select list of simple species. However, the in-situ measurements used in this project, particularly on intermediates, will lead to valuable information for predictive model development. This improved understanding of reaction rates and the kinetic models developed with this project have already produced advanced strategies for reactor design and improved methods for commercial system optimization.

TECHNICAL APPROACH AND RISKS: This work continues the experimental approach from earlier years. However, this is the final year of experimental data gathering to be incorporated into the overall model, now in the early stages of development. Earlier effort on this project has produced a good understanding of the reactivity of aliphatic C,H,O systems and has resulted in verified model predictions for the reactivity of feeds of this type. The FY 1996 work added the behavior of C,H,O aromatic species to this model. The behavior of chlorinated systems has been characterized as well. There are three important issues remaining to be resolved. First, the oxidative reactivity of nitrogen must be determined,

as organic nitrogen such as in pyridine and urea, and as nitro groups that are found in many energetic materials. Second, the method by which the model for pure feeds handles mixtures will need to be refined. It is certain that a fast reacting component will affect the reactivity of a more robust component. However, the extent to which this is important will need to be quantified. Finally, the behavior of polyaromatics will have to be explored to determine if there are special considerations for certain types of feeds that contain organic solids.

ACCOMPLISHMENTS: In FY 1997, experimental work on the reactivity of N_2O in supercritical water was completed. N_20 was found to be a relatively unreactive oxidizer. Data in the literature seems to indicate that it does not generally appear in the gaseous effluent for processing nitrogen-containing material; however, it is a logical precursor to the formation of N_2.

One paper, "Oxidation Rates of Common Organic Compounds in Supercritical Water," was accepted for publication in the Journal of Hazardous Materials, August 1997. A new paper, "Direct Observation of H_2O_2 During Alcohol Oxidation by O_2 in Supercritical Water," was submitted to *Industrial Engineering Chem. Research*, September 1997.

TRANSITION: In addition to presentations at technical meetings and publication in the reviewed literature, results from this project are made available to a wide distribution within the SCWO technical community. Additional transition will occur with indirect support on leveraged projects with the Defense Advanced Research Projects Agency and the Office of Naval Research for shipboard waste; the U.S. Army Applied Research, Development and Engineering Center's Pine Bluff Arsenal Unit; and at the U.S. Army Aberdeen Proving Ground.

PROJECT SUMMARY

PROJECT TITLE & ID: Lead-Based Paint Hazard Mitigation; CP-521

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratory - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. Ashok Kumar

FY 1998 FUNDS: $750K

OBJECTIVE: The technical objective of this project is (1) to develop and demonstrate novel vitrification technology using thermal spray or microwave energy for lead-based paint removal and disposal that can be used effectively for immobilization of heavy metal hazardous waste and (2) to evaluate emerging technologies for lead-based paint abatement including in-place management, sponge blasting, environmentally friendly chemical strippers, and cryogenic blasting. Currently used abatement technologies result in the emission of hazardous lead dusts as well as hazardous waste. Environmental contamination by fugitive dust emissions is regulated under the Clean Air and Water Acts while the Resource Conservation and Recovery Act (RCRA) addresses the proper disposal of lead-bearing wastes.

BENEFIT: The research and development of lead-based paint abatement technologies will reduce the cost of lead-based paint hazard mitigation which is estimated to exceed $1 billion for Department of Defense (DoD) installations. The most significant benefit of this work is the optimized management of lead-based paint hazards and the increased protection of the health of DoD personnel and their families. Enhanced quality of life for the soldiers and their families leads to increased troop retention and a more capable force.

TECHNICAL APPROACH AND RISKS: The technical approach for the first objective involves the preparation of vitrified materials and determining characterization techniques for the hazardous waste incorporation into the glass structure and immobilization. The mechanisms of vitrification and ion-leaching processes will be modeled to optimize hazardous waste immobilization. This model will be used to engineer durable, designer glass compositions for vitrification of lead-based paint. The application processes involve using thermal spray or microwaves for brick, masonry, concrete and wooden structures. The approach for the second objective is to evaluate the efficacy and cost-effectiveness of emerging technologies for in-place management and removal of lead-based paint including cryogenic blasting, environmentally friendly chemical strippers, sponge blasting, and laser stripping. A decision tree will be developed to select the optimum technology for lead-based paint hazard mitigation based on a paint condition index.

ACCOMPLISHMENTS: In FY 1997, to address concerns with the potential fire hazards associated with microwave lead paint removal process, nonflammable combination of coatings were evaluated. Coatings containing lead stabilization compounds such as PreTox were applied in conjunction with microwave

susceptor graphite. These coatings were commercially available and formulated to stabilize the lead carbonate pigment present in the paint. PreTox contains cement clinker compounds which react with lead and form nonhazardous waste as determined by Toxicity Characteristic Leachate Procedure testing. The temperature needed to soften the lead based paint by microwaves for easy removal is about 100°C. By using a cementitous coating in the PreTox, the fire hazard is reduced.

The lead based paint hazard management system (LHM) was completed and ready for alpha testing. LHM is jointly developed by the Army and Navy and takes data from paint inspections, lead dust, and soil samples to produce a lead hazard management plan and the required lead hazard disclosure report. Data from Army installations such as Carlisle Barracks, PA, were put in the system and a hazard abatement plan developed and presented to the installations engineers.

TRANSITION: Transfer of the technology is occurring via DoD demonstration/validation in Environmental Security Technology Certification Program-funded projects for thermal spray vitrification and microwave paint removal. Collaboration with the private sector includes: licensing agreements for patents, CRADA development, commercialization efforts, and journal articles and presentations at trade shows. Additional documents are being developed for use by the Tri-Service user community, including Guide Specifications, Technical Manuals, and User Guides and an ASTM standard for abatement of lead hazards in buildings.

PROJECT SUMMARY

PROJECT TITLE & ID: Controlling, Assessing, Managing, and Monitoring the Noise Impact from Weapons, Helicopters, and Aircraft on Training; CP-523

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratory - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. Paul Schomer

FY 1997 COMPLETED PROJECT

OBJECTIVE: Preservation of the Department of Defense (DoD) training, testing and readiness mission requires that DoD be capable of controlling assessing, managing, and monitoring noise problems in the vicinity of its bases and installations. In terms of human response, the DoD continues to have difficulty meeting National Environmental Policy Act (NEPA) compliance requirements and executing the Air Installation Compatible Use Zone (AICUZ) Programs because there is a lack of adequate scientific data on the effects of environmental noise from DoD operations on the health and welfare of people. The DoD requires the ability to assess the combined/cumulative human impacts of joint and/or co-located installations and operations. For example, the DoD has been receiving major challenges to environment impact analysis documents because it does not currently address the combined and cumulative effects of Army and Air Force operations there.

BENEFIT: The results of this research and development program significantly contributed to protecting the operational capability of military installations to perform their readiness mission while minimizing noise impacts.

ACCOMPLISHMENTS: In FY 1997, a comparative study of human response to blast noise and sonic booms was completed, and a draft American National Standard for Combined Noise Method was completed and balloted. All of the noise data collected at the Naval Air Station Fallon was analyzed. A draft report on the new Fallon data has been completed. The original Fallon report has been formatted for publication purposes. American National Standards Institute (ANSI) standard on combined method approved by board of standards review and sent to publisher.

TRANSITION: Transition of the results of this project is occurring via publication of the National and International Standards and their use by DoD.

PROJECT SUMMARY

PROJECT TITLE & ID: Evaluation of the Use of Waste Energetics as Supplemental Fuels; CP-524

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Surface Warfare Center - Indian Head, MD

PRINCIPAL INVESTIGATOR: Mr. Tim Dunn

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective of this project was to develop technology for using waste energetic materials to supplement fuel oil in the feed to a steam-generating boiler. This technology recovers the energy content of the energetic material and provides an alternative to open burning/open detonation (OB/OD).

BENEFIT: This technology will provide evidence to support industrial scale trials. Industrial use of excess energetics will alleviate Department of Defense (DoD) stockpiles and make use of the materials' heat content which is wasted by other methods. Furthermore, states are expected to limit permits for the alternative, OB/OD. Finally, this technology allows for the controlled discharge of exhaust emissions, which cannot realistically be done with OB/OD.

ACCOMPLISHMENTS: In FY 1997, the regulatory review by Indian Head Division of Naval Surface Warfare Center (NSWC) personnel was completed. The Trinitrotoluene (TNT) and Comp. B tests were completed. One percent, five percent, and ten percent TNT in toluene and fuel oil were burned. The ten percent TNT test involved a significant slurry. Plugging problems occurred early and were resolved by removing an in-line strainer and a secondary check valve and quick-disconnect. The one percent and ten percent Comp. B tests were completed without plugging. The only problem seen with these tests were that RDX particles that make up Comp. B settled rapidly after the level dropped below that of the agitator. Additional fuel oil and manual assistance resolved the problem. NOx levels were less than expected. The NOx analyzer was checked against multiple standards and was found to function adequately. All results to date are positive. The safety review was started and interface dimensions reviewed.

TRANSITION: Transitions plans include: transition of this project through Defense Environmental Restoration Account (DERA) and Environmental Security Technology Certification Program (ESTCP), inviting waste energetic stockpile locations to witness full scale demonstrations; distribution of videos, brochures, reports, and cost analyses to all installations with energetic demil accounts; and investigation of private sector interest.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Education and Training Center (NEETC); CP-819

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg

PRINCIPAL INVESTIGATOR: Dr. Raymond Lovett

FY 1998 FUNDS: $1500K

OBJECTIVE: Implementation of new environmental technology in "green processes" or to remediate contaminated sites has been difficult for a variety of reasons, including: facilitating technology transfer; technology selection; and technology implementation. These difficulties may be alleviated by improving evaluation tools for characterizing and assessing innovative technology development that result in better and more accessible academic training in environmental health and safety.

BENEFIT: This safety and health evaluation tool, when coupled with existing "engineering and decision and management tools" will assist designers and technology gatekeepers to evaluate and assess safety and health issues in a focused, systematic way during the development of their technologies; minimize their occurrence before and during end-user implementation; and ensure worker safety and health training to achieve safe operation of the technology is available at startup.

TECHNICAL APPROACH AND RISKS: Develop a knowledge-based system prototype (TECHXPERT) that will evaluate and incorporate worker environmental safety and health issues in the design of innovative hazardous technologies. When coupled with existing "engineering design and management tools", this system will lead designers and developers through a thorough, complete, systematic consideration of "downstream" worker and environmental safety and health implications associated with field (or production) use of their technology.

Implement TECHXPERT on the World Wide Web. The new system will provide new technology developers with access to an "occupationally and environmentally focused total system design assessment tool" through a World Wide Web site that will be linked to data bases and software tools on safety and health associated with known technologies (Environmental Protection Agency formats), risk assessment, preliminary hazard recognition and analysis, fault-tree analysis, job safety analysis, etc.

ACCOMPLISHMENTS: At a meeting held with the Technology Education and Training Advisory Taskforce (TETAT) in June 1997 in Alexandria, VA, thirty experts on new environmental technology education and implementation discussed current training needs and provided input on areas where National Environmental Education and Training Center (NEETC) might advance current efforts. The environmental education and training data base was completed. This data base includes information on four year

institutions, two year schools, and military and union training programs and is now available on computer disk with an operating manual. The National Model Environmental Health and Safety Curriculum (2000 copies) was completed. The synopsis of both the Safety in New Technology meeting and the TETAT meeting was completed.

TRANSITION: Transition is an ongoing part of this SERDP-funded project and consisting of full implementation of an expert system available on the Internet or on diskette; demonstration at two technology development sites; integration with a similar DOE program; and implementation of an outreach program.

PROJECT SUMMARY

PROJECT TITLE & ID: Demonstration of Compact, Closed Loop Controlled Waste Incinerator; CP-887

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center - China Lake, CA

PRINCIPAL INVESTIGATOR: Dr. Klaus Schadow

FY 1998 FUNDS: $740K

OBJECTIVE: The objective of this project is to apply the technical basis of new Compact, Closed-Loop Controlled Waste Incinerator technology developed in project **CP-034** to two specific Navy incinerator programs: (1) development of a compact and efficient afterburner for a plasma arc thermal destruction system; and (2) a sludge incinerator for black water destruction.

BENEFIT: Successful shipboard demonstration of a compact incinerator with real-time exhaust monitoring for active combustion control represents a significant step towards assured waste incineration and can be the basis for the next generation incinerators. The compact-incinerator technology will be essential for the development of environmentally sound ships beyond the year 2000. Compact incinerators are also desirable for on-shore use in the government and private sector. Small, compact incinerators will allow on-site waste destruction and avoid waste transportation to large incineration sites. In particular, medical waste incineration is a prime candidate in the private sector for a compact system. The closed-loop active control of the incineration process will for the first time assure proper incineration during design and off-design operation. Successful demonstration of the assured waste incineration on-board ships will result in significant cost savings by avoiding cost for waste off-loading and on-shore destruction, particularly in foreign countries.

TECHNICAL APPROACH AND RISKS: The plasma arc system will be explored for ship-board waste management under an Advanced Technology Demonstration (ATD) program which starts in FY 1997. The black water incinerator, which is being used on different classes of Navy ships, is presently being up-graded under Naval Sea System Command funding. The SERDP technology will be enhanced to increase the throughput and treat concentrated sludge derived from black and gray water as well as sludge derived from oily wastes.

A two-phase demonstration program will be undertaken. In the first phase, two Process Development Unit (PDU) demonstrations will be carried out. Existing equipment will be modified and existing control components will be used. In the second phase, a demonstration of optimized systems will be conducted with the advanced control components and enhanced physical understanding which is being developed under project **CP-034**. The afterburner PDU demonstration will be primarily based on recent SERDP

scale-up experiments using controlled vortex combustion with standard actuators and sensors, a simple time-delay controller, and open-loop control. Cold pyrolysis gases initially will be used. The sludge incinerator PDU demonstration will be based on recent Environmental Protection Agency (EPA) supported experiments using resonant acoustics for increased solid waste pyrolysis.

For the demonstration of the optimized afterburner, critical features of the trapped vortex concept will be integrated into the actively controlled concept. The design will be modified for the use of realistic (hot) pyrolysis gases. Subsequently, advanced sensors and actuators as well as an adaptive controller for closed-loop control will be used. The performance of the new, compact, actively controlled incinerator will be compared with alternative disposal options (both current and other possible technologies). For the optimized sludge incinerator, a design based on the emerging Science and Technology (S&T) results will be developed and tested.

ACCOMPLISHMENTS: Progress was made to: (1) scale-up critical injector geometries of the 50kW afterburner to the 1MW power level, which corresponds to 2 tons of waste per day; (2) successfully demonstrate performance of the full-scale afterburner and (3) establish baseline conditions for the acoustically enhanced sludge incinerator. For the controlled afterburner, testing continued with the addition of benzene to the simulated pyrolysis gases. This allowed Destruction and Removal Efficiency (DRE) to be measured. It was shown that the enclosed system has the same performance characteristics as prior versions tested at China Lake. At optimal operating conditions the DRE of this compact system was consistently above four nines and as high as five nines while maintaining low NOx, low CO and hydrocarbon emissions.

Project results were presented at the 1997 International Conference of Incineration and Thermal Treatment Technologies, May 1997, in Oakland CA. Additional significant progress was made in full-scale performance experiments of both the actively controlled afterburner and the sludge incinerator. Papers on both topics were presented at the Western State Section/Combustion Institute Spring Meeting held at Sandia Laboratories and at the Fifth International Congress on Hazardous Combustion Byproducts held at the University of Dayton.

TRANSITION: Continuing interaction is taking place with the Navy for: multi-functional incinerators (for sludge and oil); demonstrating acoustics retrofits; developing an afterburner for another DoD facility under a joint development program. Three marine incinerator manufactures with an interest in collaboration have been identified and a proposal for collaboration with one has been developed. The Principal Investigator is pursuing future DoD funding for a compact, integrated system for hazardous waste incineration at DoD facilities and for 6.4 research funding for shipboard advanced incineration.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Non-Thermal Plasma Reactor Technology for Control of Atmospheric Emissions; CP-1038

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Los Alamos National Laboratory - Los Alamos, NM

PRINCIPAL INVESTIGATOR: Dr. Louis Rosocha

FY 1998 FUNDS: $575K

OBJECTIVE: The overall project objective is to evaluate and develop new non-thermal plasma (NTP) reactor technology for Department of Defense (DoD) air emissions control applications and provide a basis for selecting the most appropriate NTP technology for DoD application. This will be accomplished by evaluating the performance of prototype and pilot-scale NTP reactors (i.e., corona, dielectric barrier, and electron beam) for Nitrogen Oxide (NOx) and Hazardous Air Pollutant (HAP) abatement and specialized Volatile Organic Compound (VOC) control. The development of an efficient, reductive-model NOx processor is a key goal.

BENEFIT: All organizations (DoD, Department of Energy (DOE), industry) affected by the need to control emissions of NOx and HAPs/VOCs will benefit from the development of a flexible technology for emissions control and a basis of selecting the most appropriate technology for specific needs. With the successful development and implementation of NTP technology, present and planned missions can proceed without deleterious environmental impacts or major compliance-issue and cost escalations. Particular technical impacts are an increase in the efficiency of electric-discharge NTP (by control of discharge physics and plasma chemistry) and the potential for development of low back-pressure, filterless, scrubberless NOx control equipment using reductive mode processing (i.e. go to N_2 and O_2 terminal products), effected by improved electrical driver technology. Also, other VOC-abatement technologies are not yet fully proven, so NTP can be a promising back-up in some cases.

TECHNICAL APPROACH AND RISKS: In the first year, a comparative assessment of electric-discharge driven and electron-beam driven NTP reactors was performed, and reaction kinetic models and predictive, reactor simulation model were developed. In the second year, reactor scaling criteria and optimization models will be developed and scaling studies will be initiated with laboratory-pilot apparatus. In the third year, reactor scale-up, optimization, and system engineering will be completed to the point of starting the design of a field-pilot unit. The fourth year will concentrate on constructing and testing a field-pilot unit at a selected DoD site and providing criteria for selecting the most appropriate NTP technology for DoD applications. A cost-benefit assessment for NTP technology application to NOx and VOCs will be addressed as part of this project.

The comparative assessment work will build upon a 1995 National Institute of Standards and Technology (NIST) workshop on NTP applications to air pollution control. NIST will also assist in plasma chemistry model development and laboratory measurements of reaction-chemistry relevant parameters. Reactor performance measurements will be carried out using gas chromatography/mass spectrometry, tunable diode laser, and laser induced fluorescence (LIF) probes, with Army Research Laboratory (ARL) taking the lead on optical/laser measurements. ARL will also carry out CFD (computational fluid dynamics) calculations to predict and optimize fluid flow patterns and treatment residence times. Los Alamos will focus on electric discharge physics, electrical drive circuit engineering and optimization, and the design and construction of laboratory test, pilot, and scaled-up reactors.

NTP technology is frequently an energy-intensive process that sometimes produces undesirable byproducts. The risk is being able to minimize these byproducts while reducing the energy consumption. Electron-beam NTP technology is further hampered by the availability and life of vacuum-separator windows and attendant energy losses in these foils from low-energy electrons.

ACCOMPLISHMENTS: In FY 1997, four laboratory-prototype NTP reactors have been 90 percent machined; electrical-diagnostics instruments have been ordered. The laser-induced fluorescence equipment has been set up at ARL and is being prepared for reactor measurements. Design and construction of a lab-scale prototype reactor was completed. The Ion-molecule reaction pathways for NOx and reactive organic gases (ROGs) were identified and the LIF setup and the test-case combustion fluid dynamic modeling runs were completed. Finally, laboratory-scale NOx-removal experiments were completed with the pulsed corona and dielectric barrier discharges and the baseline design for the hybrid plasma-absorber was completed.

TRANSITION: The transition plan for this project involves coordination with users; coordination with industry; and full-scale implementation within DoD/DOE. User coordination includes: Air Force NOx abatement projects; jet-engine test cell and diesel-engine NOx abatement and VOC control at Tinker Air Force Base; emission control for "burn Box" at the Army's Aberdeen Test Center; and multi-agency interfacing via Los Alamos Environmental Management (EM) and DoD Program Manager. Industry coordination includes existing technology-commercialization Cooperative Research and Development Agreements (CRADAs) with Electric Power Research Institute (EPRI) and High Mesa Technologies (HMT); potential future CRADAs with HMT and Environmental Elements; and Los Alamos Industrial Partnership Office promotion of industrial interaction. An industrial partner will be identified during the transition phase of this project and full-scale implementation will occur through a Demonstration/Validation Project with Environmental Security Technology Certification Program (ESCTP).

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Integration of Laser-Based Sensors for VOC/NOx and Metals Emissions Monitoring; CP-1060

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Sandia National Laboratory - Livermore, CA

PRINCIPAL INVESTIGATOR: Dr. Scott Bisson

FY 1998 FUNDS: $1040K

OBJECTIVE: The objective of this project is to develop a combined laser-based system for monitoring Volatile Organic Compound/Nitrogen Oxide (VOC/NOx) and metals for compliance with the Clean Air Act Amendments of 1990. For gaseous pollutants, an infrared (IR) spectrometer based on the new, periodically-poled, lithium niobate (PPLN) laser technology will be used. For metals emissions monitoring, the technique of laser induced breakdown spectroscopy (LIBS) will be employed.

BENEFIT: If successful, this technology would allow, for the first time, near real time, in-situ analysis for monitoring a wide range of species (metals and gases) with higher sensitivity than previously achievable. There are also potential applications in process control and atmospheric chemistry research. Moreover, the compact size of this new system is attractive and its cost is anticipated to be competitive with many conventional, laboratory analytical services.

TECHNICAL APPROACH AND RISKS: For development of the IR Spectrometer, the tunability, spectral bandwidth, and oscillation threshold of the PPLN source will be characterized. Given the wide range of species to be detected and the fact that the absorption spectra span the infrared, broad tunability will be essential. Reduction of the oscillation threshold will be attempted. The detection sensitivity will also be optimized through the use of acoustically resonant cells.

For development of the portable LIBS, currently available solid-state diode lasers will be identified and evaluated for long-term operation. The feasibility of using a solid-state laser for plasma ignition and spark generation will be investigated. If successful, this would reduce the physical dimension and weight of the LIBS system substantially and move one step closer to the portable unit proposed. Other compact lasers such as a diode-pumped Nd:YAG laser will also be evaluated. A thumbnail-sized microspectrometer will be employed for the portable LIBS system (patent-pending).

For actual hardware integration, the goal is to exploit commonality between the IR spectrometer and the LIBS instrument to the extent possible but without sacrificing performance. Three areas of instrumental commonality between the two components have been identified. These are the laser source, the sample interaction region, and the operating software. During the course of the integration phase, the feasibility

of sharing these components in the integrated system will be determined. A common laser must serve the dual purpose as a pump source for the PPLN laser and a spark source for the LIBS measurement. The final sensor systems will be packaged for specific industrial or environmental applications and marketed by commercial partners.

ACCOMPLISHMENTS: In FY 1997, a second generation infrared optical parametric oscillator (OPO) based on periodically poled lithium niobate was developed. A diode-pumped Nd:YAG laser system was procured from COHERENT laser company. Testing intra-cavity components for continuously tunable PPLN laser source has begun. Pulsed photoacoustic spectroscopy measurements and established sensitivity limits were conducted. The LIBS system was calibrated for open air composition, the lasers were combined to reach energy output range from 1 mj to 1.2 J per pulse and the LIBS system is being calibrated for water vapor interference.

TRANSITION: The transition plan for this project includes teaming with a commercialization partner midway through FY98. Potential partner, Spectrum Diagnostix, currently is marketing Continuous Emissions Monitors. Additional partners include Lightwave Electronics and Coherent, both of whom have expressed interest in the laser source development. A demonstration/validation phase will be required prior to commercialization.

PROJECT SUMMARY

PROJECT TITLE & ID: Detect and Identify Multiple Hazardous Air Pollutants (HAPs) at Extended Distances; CP-1061

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Research Laboratory - Washington, D.C.

PRINCIPAL INVESTIGATOR: Dr. Phillip Sprangle

FY 1998 FUNDS: $245K

OBJECTIVE: The objective of this project is to develop a new class of active remote sensing sources and techniques for the detection and identification of hazardous air pollutants (HAPs). Active remote sensing with ultra broadband (UB) radiation can provide real-time ranging and identification of HAPs at extended distances.

BENEFIT: The application of UB radiation sources to remote sensing can lead to the identification, ranging, and detection of HAPs at extended distances through simultaneous spectral response from various HAPs. It will allow the tracking of major HAPs such as nitrogen oxides (NOx) and others (ClOx, SOx). It is also especially valuable during night time monitoring when sunlight is not available for conventional remote sensing methods. A system of active remote sensing using UB radiation will benefit efforts on continuous real-time identification of HAPs that are of concern to Department of Defense (DoD).

TECHNICAL APPROACH AND RISKS: UB radiation can be generated in a nonlinear optical medium with picosecond laser pulses. The mechanism for the generation of UB radiation is based on self-phase modulation in nonlinear medium. Continuous UB radiation can be generated with extremely high efficiency and high average power by beating two laser beams with slightly different frequencies in a nonlinear medium. The bandwidth of the radiation can extend from the optical to the Infrared (IR) regime. UB radiation can provide the necessary illumination required for active remote sensing. The source size of the UB radiation is extremely small, which allows for beaming the radiation over extended distances of several kilometers.

The generation of UB radiation in various nonlinear material will be analyzed and evaluated using existing laser facilities at the Naval Research Laboratory (NRL). Lasers with optical and near IR wavelengths will be used to generate UB. The conversion efficiency and bandwidth will be optimized by selecting the appropriate nonlinear medium. The quality of the UB radiation beam will be measured and its propagation in air characterized. The methodology and diagnostics necessary to evaluate the UB spectrum are based on hyperspectral imaging techniques that are presently being developed at NRL. Proof-of-principle experiments on active remote sensing will be performed. Data reduction techniques for analyzing complex spectral signatures will be studied.

ACCOMPLISHMENTS: Beatwaves have been generated using one laser beam and the simulated Raman Scattering process to create one or more Raman sidebands. Two laser frequencies were generated using two laser heads in the same laser. The initial beatwave generation using Raman cells at the 1996 American Physical Society Annual meeting and the theoretical analysis and simulation of UB radiation generation using laser beating were documented in a Naval Research Laboratory Memorandum report.

TRANSITION: The Transition Plan includes further development and demonstration within SERDP, including testing of the device in a field environment. Additional transition could occur in Small Business Innovation Research (SBIR) Phase I and II leading to Cooperative Research and Development Agreement (CRADA) Programs.

PROJECT SUMMARY

PROJECT TITLE & ID: Plasma-Assisted Catalytic Reduction of NOx; CP-1077

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base

PRINCIPAL INVESTIGATOR: Dr. Joseph Wander

FY 1998 FUNDS: $390K

OBJECTIVE: This project will extend bench-level observations of the cold-plasma-induced catalyzed chemistry of propene in simulated combustion-exhaust gases to include mixtures of fuel constituents common to JP-8 in actual combustion exhaust. The cost and performance data from this exercise will be used to project an estimated cost/benefit for a full-scale control process and to design a pilot-scale device for assembly. In FY99, the project will assemble and evaluate a pilot-scale Nitrogen Oxide (NOx)- (and particulate-) control device implementing the plasma-assisted selective catalytic reduction (SCR) concept as refined during FY98. Data from the pilot-scale test will support estimates of the cost and performance of operating this technology as a full-scale emission control process.

BENEFITS:
1. Option to operate diesel-powered equipment at greater than 95 percent of baseline performance and fuel efficiency while emitting less than 10 percent of baseline pollutants.
2. Definitive determination about economic feasibility of catalytically augmenting plasma-induced chemical conversions.
3. Advance state-of-the-art in SCR and other catalytic processes.

TECHNICAL APPROACH AND RISKS: The technology has been demonstrated at bench scale to partially oxidize NO (to NO_2) and propene in simulated exhaust gases and to accomplish efficient conversion of the mixture so generated into N_2, CO_2, and water. This project will extend the state of development through a definitive, pilot-scale, proof-of-concept demonstration on a representative Department of Defense (DoD) combustion source.

In FY98, the work will explore at bench level the enhancement of SCR of NOx by cold-plasma-induced activation of progressively more complex mixtures containing constituents of JP-8. Experimental targets include Destruction and Removal Efficiency (DRE), product composition, tolerance to and fate of soot, power consumption, and catalyst lifetime. When the chemistry is understood sufficiently, in FY99 we will design, build, and test a pilot scale (~50 cfm) treatment system on a split of the exhaust from a diesel engine.

Very high efficiency for NOx reduction has been achieved for bench-scale flow rates using propene as the

reductant. The main technical risk is maintaining the high efficiency for NOx reduction when the flow rate is increased to the pilot-scale and when diesel fuel is used as the reductant.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: After one year, a scaled-up prototype will be delivered for field testing, followed by a full scale technology demonstration the next year. The technology is expected to be ready for transition to an Environmental Security Technology Certification Program (ESTCP)-type demonstration and evaluation within two years. A commercial partner, Cummins Engine Co., is committed to deploying this technology as soon as it is technologically and economically viable.

PROJECT SUMMARY

PROJECT TITLE & ID: Enzymes for Degradation of Energetic Materials and Demilitarization of Explosives Stockpiles; CP-1078

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: Department of Energy

LAB: Pacific Northwest Laboratory

PRINCIPAL INVESTIGATOR: Dr. Manish Shah

FY 1998 FUNDS: $300K

OBJECTIVE: The objective of this project is to develop a safe, economical and environmentally sound process where biocatalysts (enzymes) could be used for degradation of energetic materials with an option of converting them into value added products. The proposed process can operate at room temperature and atmospheric pressure in aqueous phase and is very different than a microbial process as it can tolerate high concentration of explosives or solvents and will use catalyst with highest activity per unit weight of the catalyst. The process does not employ open burning or open detonation (OB/OD) to destroy energetic materials. It can stand by itself or can augment/support other technologies for treatment of energetic materials. An enzyme based process will also provide an alternative of converting explosives into commercially valuable chemicals, as the transformation process can be controlled to accumulate a desired intermediate. The proposed technology will not release any air pollutants; the proposed enzyme technology will meet the regulations of Clean Air Act amendments, Resource Conservation and Recovery Act (RCRA) and Federal Facilities Compliance Act (FFCA). The development of enzyme technology is possible now due to recent developments in enzyme technology. Robust and active enzymes can now be developed which can withstand harsh reaction environment. Such robust enzymes are developed by cross linking enzyme crystals (CLEC). Alternatively, inexpensive enzymes can be used as disposable catalysts as evidenced by their use in the detergent and food industries.

BENEFITS: Enzymes have highest reactivity per unit weight of catalyst, and the process operates under mild and safe conditions. It can be performed at room temperature, atmospheric pressure, and in aqueous phase, nor does it require any special equipment hardware or software and thus has very low capital cost. A mobile system can be designed without any major technical or cost hurdles. Enzymes can be produced at low cost and in large scale by enzyme manufacturers. It is believed that proposed enzyme technology will attack these explosives even in the presence of plasticizer, wax, aluminum, and other organic chemicals. Enzyme technology has the potential to offer features which are currently not available with either incineration, Molten Salt, or Supercritical Water Oxidation (SCWO) processes at low cost. Special features of the proposed enzyme technology are: excellent kinetics, no special equipment hardware and thus low capital cost, enzymes can be stabilized to work under harsh conditions (solvents, high concentration of explosives, etc.), highest reactivity per unit weight of any catalyst, simple process to operate, mobile system can be designed, enzymes can be sprayed in remote location, low operating cost, enzymes can

operate at room temperature and atmospheric pressure, and enzymes can be produced at low cost for large scale application.

TECHNICAL APPROACH AND RISKS: The overall technical approach for the proposed research involves the transformation of munitions such as TNT, RDX, and HMX in different forms (composition A, B, C, D, H-6, Tritonal) to intermediate products using enzymes. The intermediate products, in some cases, are expected to have reduced or no toxicity and thus will be evaluated for their approval for disposal by the regulatory agencies. In other cases, the intermediates could be used as a feed stock in the chemical industry or destroyed to carbon dioxide and water using microbial and/or chemical processes. The toxicity of the intermediate products and final products will be evaluated.

The first need for the project is to understand the kinetics and mass transport issues involved in explosive degradation by an enzymes under heterogeneous conditions. The conversion of explosives (i.e., TNT) by enzyme catalyzed heterogeneous solid-liquid system is different from a normal heterogeneous catalytic system since the catalyst (enzyme) is in the aqueous system.

It is believed that the proposed idea has high probability of success. The proposed enzyme technology can be viewed by chemist as a free radical based process where enzymes are the source of free radical generator. By selecting different combination of enzymes, mediators, and reaction environment, one may change redox potentials of free radical. Such a flexibility was never envisaged by any earlier biological or chemical process in aqueous phase process.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: Depending on the results of this project, the transition plan includes a site demonstration with companies involved in demilitarization activities at the Naval Surface Warfare Center-Indian Head, the U.S. Army Defense Ammunition Center, and the Department of Energy Pantex Plant. Following the completion of SERDP funding, a transition to Environmental Security Technology Certification Program (ESTCP) will be pursued.

PROJECT SUMMARY

PROJECT TITLE & ID: Hypergolic Non-Detonative Neutralization in Production and Dimilitarization; CP-1079

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Sandia National Laboratory - New Mexico

PRINCIPAL INVESTIGATOR: Dr. Maher Tadros

FY 1998 FUNDS: $395K

OBJECTIVE: The objective of this program is to develop an innovative alternative technology to replace open burn/open detonation (OB/OD) operations for the destruction and disposal of obsolete, excess, and off-spec energetic materials. The Department of Defense (DoD) faces many environmental and legal issues in the demilitarization of bulk energetic materials and assembled munitions. OB/OD is unacceptable in certain locations because of problems associated with noise and shock pollution, metal splatter, and lead emissions. The DoD stockpile of energetic materials that need to be destroyed is about 700,000 tons, and this total increases at a rate of about 60,000 tons per year. The Department of Energy (DOE) also has a significant amount of weapons components which needs to be destroyed. If OB/OD is restricted or banned, then a new alternative technology must be ready to replace it.

The project will develop environmentally conscious, high throughput, cost-effective, methods for disposal of energetic materials. The initial focus will be on developing appropriate chemistry for reacting the energetic materials with a hypergolic chemical, which neutralizes the energetic materials and precludes a detonation. During the first year the program will focus exclusively on the development of effective reagents and understanding the underlying chemistry.

BENEFITS: This project will provide DoD and DOE with an alternative method for safe and effective disposal of energetic materials. These new methods will be based on chemical breakdown of the energetic materials without detonation and are expected to exhibit high throughput, cost effectiveness, and possibilities for reuse/reapplication of the byproducts.

TECHNICAL APPROACH AND RISKS: Our proposed approach uses organic amines, metal alkyls, or amine-metal alkyl adducts to neutralize explosives. Organic amines and metal alkyls have been shown to react hypergolically with the Trinitrotoluene (TNT), Composition B, and RDX. A few grams of these chemicals have been shown to be capable of initiating the autocatalytic self consumption of up to 7 kg of TNT and Composition B in field tests. If larger quantities of the chemical initiators are used or the initiators are diluted with solvents, the reaction is not hypergolic; instead, it results in the formation of a tarry residue which has been shown to be non-detonable. Detonation has never occurred in numerous field tests in which the autocatalytic self consumption of the explosive has been initiated with the above

chemicals, even though the explosive was confined during the decomposition process. The chemistry related to the interaction of organic amines and metal alkyls with explosives is poorly understood and one objective of this program is to further elucidate the reaction mechanisms. Two approaches will be used for the pre-treatment of explosives. Overall, the two proposed approaches have great potential in the pre-treatment of explosives to produce a non-detonable product for reuse or final treatment in the steam reforming reactor. However, it will be necessary to study the mechanisms and kinetics of the chemical reactions to enable development of a reliable technology applicable to a wide range of energetic materials.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: The technology developed under this project will be made available to users within DoD and DOE, including partners for prior collaborative efforts. Conventional chemical processing equipment is adequate for full scale implementation of this technology.

PROJECT SUMMARY

PROJECT TITLE & ID: Optimization of an Innovative Biofiltration System as a VOC Control Technology for Aircraft Painting Facilities; CP-1104

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Air Force

LAB: Air Force Research Laboratory

PRINCIPAL INVESTIGATOR: Dr. Kerry Kinney - University of Texas at Austin

FY 1998 FUNDS: $87K

OBJECTIVE: Until alternative coating materials and depainting operations become available, treatment of fugitive Volatile Organic Compound (VOC) contaminant releases during application or removal of coatings is necessary to maintain compliance with the Clean Air Act Amendments of 1990. Currently available VOC emissions control technologies are costly at the high volumetric flow rates and low contaminant concentrations associated with the ventilation of aircraft hangars.

This project will develop an innovative, high flow-rate biofiltration method for treating VOC-laden air emissions. Biofiltration of painting off-gas streams is currently limited, not because of insurmountable technical problems but simply because current systems have not been designed to handle the operating conditions typical at these facilities. To address the limitations described above, innovative design features and biofilter configurations will be investigated, tested, and applied to an actual Air Force paint spray booth.

BENEFITS: The project will provide a stable biofiltration system for paint spray booth applications that operate intermittently and emit varying quantities of volatile organic compounds. Typical biofilter problems such as long acclimation times, slow response to load changes, and biomass clogging will be overcome. The innovative biofiltration process developed by this project will, therefore, be suitable for venting of aircraft hangars during application or removal of coatings. It has the added advantages of operating at ambient temperatures and minimizing the generation of secondary wastes.

TECHNICAL APPROACH AND RISKS: The following innovative design features will be investigated for their ability to improve biofilter performance for paint spray booth applications: (1) A recirculating inoculation method to shorten the bioreactor start-up period; (2) Directionally-switching operation to improve biomass distribution and prevent clogging; (3) Slip stream feed to maintain high biomass activities during paint spray booth shutdown periods; and (4) An aerosol nutrient delivery system to efficiently deliver nutrients and moisture to the biofilm. Since bioreactor performance is strongly influenced by the contaminants being treated, the effectiveness of each of the design modifications will be determined under single (e.g., ethyl acetate) as well as multiple [e.g. Methyl Ethyl Ketone (MEK), Methyl Isobutyl (MIBK), toluene] contaminant conditions representative of paint spray emissions. Previous studies have shown that

the degradation of methyl isobutyl ketone, in particular, is adversely affected by the presence of MEK. Other risk areas are whether stable and effective long-term operation can be achieved while operating in a directionally-switching mode and using an aerosol nutrient/moisture delivery system.

The first part of this work will focus on constructing experimental reactors and investigating and optimizing the recirculating inoculation method and the directionally-switching design modification through a series of laboratory-scale experiments. A total of three bioreactors packed with artificial media will be utilized in this study, two laboratory-scale units and one pilot-scale unit. The modified pilot-scale bioreactor will be tested at an actual paint spray booth facility located at Kelly Air Force Base in San Antonio, Texas.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: The primary users of the biofilter technology will be Department of Defense paint spray booth facilities; however, the technology also will be widely applicable to the private sector. Research results will be published in forums that reach a large audience of professionals in air pollution control including the Annual Meeting of Air and Waste Management Association. A web site also will be dedicated to the proposed research and will include brief statements related to research objectives and interim results.

PROJECT SUMMARY

PROJECT TITLE & ID: Membrane-Mediated Extraction and Biotreatment of VOCs; CP-1105

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Environmental Protection Agency

LAB: National Risk Management Research Lab

PRINCIPAL INVESTIGATOR: Mr. Norman Kaplan

FY 1998 FUNDS: $475K

OBJECTIVE: Until alternative coating materials and depainting operations become available, treatment of fugitive Volatile Organic Compound (VOC) contaminant releases during application or removal of aircraft coatings is necessary to maintain compliance with the Clean Air Act Amendments of 1990. Currently available VOC emissions control technologies are costly at the high volumetric flow rates and low contaminant concentrations associated with ventilation of paint spray booths.

In conjunction with the recently developed partitioned recirculation flow reduction technique, this project will develop a novel Membrane BioTreatment (MBT) system, which combines a first-stage microporous, polypropylene, hollow-fiber membranes unit to extract and concentrate VOC contaminants into a low-volatility organic stripping fluid, with a similar second-stage membrane unit in which the VOCs are extracted into a nutrient medium for biotreatment. VOC contaminants are completely metabolized by the microorganisms. Independent operation and optimization of each stage of the process will accommodate intermittent painting operations and reduce equipment size.

BENEFITS: This proposed treatment will minimize the volumetric flow of contaminated air to be treated, concentrate the VOCs to reduce the size and cost of control equipment, and then completely destroy the VOCs without producing a secondary waste stream. These advantages make this VOC treatment a viable option over a broad range of spray booth sizes.

TECHNICAL APPROACH AND RISKS: The work will be conducted in two phases, with appropriate decision points throughout the program. In Phase I, process streams will be characterized at bench scale to show technical feasibility using simulated streams composed of one or more organic constituents found in aircraft coatings and by using representative exhaust from a laboratory spray booth using aircraft topcoats. Mass transfer coefficients will be evaluated using octanol, sunflower seed oil, and mineral oil as stripping fluids for at least one organic contaminant. The goals are to identify the most effective stripping fluid and to establish a mathematical relationship between stripping fluid flow, contact time, and VOC removal efficiency. A series of experiments will also be conducted to determine the stripping efficiency of a bench-scale biotreatment module, with and without biofilms present, to account for the additional resistance added by the biofilm simultaneous with degradation of the VOC contaminants. Mass transfer rates, biodegradation rates, flow rates, and modular equipment sizes will be evaluated prior to

design and lab-testing of an integrated pilot scale system. A pilot MBT system will be tested in Environmental Protection Agency's (EPA) Coatings Laboratory using military paints.

In Phase II, the pilot MBT system will be evaluated at Tyndall Air Force Base to determine longer-term performance of microbes and hardware and to develop and validate scale-up parameters. Microbe performance with VOC primer and topcoat will be evaluated first individually and then under cycling operations to assess the ability of the system to respond to rapidly changing feedstock. Analysis will include on-line Gas Chromatography (GC), as well as Gas Chromatography/Mass Spectrometry (GC/MS) analysis of batch samples, to determine removal and degradation efficiencies of specific VOCs. Upon successful completion, Air Force Research Laboratory/MLQ will develop application criteria and identify installations for further full-scale testing.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: If it is determined that the technology is economically realistic, the Air Force will identify Department of Defense (DoD) sites that are potentially well-suited to adopt this technology. The sites may include both aircraft and ground equipment painting facilities. Simultaneously, EPA will develop a plan to transfer the technology to the installations identified. The sites will be provided with a jointly developed technology package. The intent is to select a full-scale demonstration site from those identified to propose a follow-on project. The technology transfer plan will include developing printed materials for direct mailing, papers and presentations for symposia.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Particulate Emission: Size Characterization and Chemical Speciation, CP-1106

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Air Force

LAB: Air Force Research Laboratory

PRINCIPAL INVESTIGATOR: Dr. Adel Sarofim - University of Utah

FY 1998 FUNDS: $689K

OBJECTIVE: The objectives of the project are to develop advanced methods for the measurement of the size distribution and composition of particulate matter (PM) emitted from mobile and stationary sources in order to provide the Department of Defense (DoD) with the tools needed to characterize and control the emissions from DoD facilities. The feasibility of using advanced analytical measurements to characterize the chemical composition and size of particulate emissions from a diverse range of sources operated by the DoD will be determined. The data obtained during the evaluation of the instruments will provide a measure of the relative importance of different DoD sources and will be useful for guiding the strategies for controlling the emissions from DoD facilities. The cost effectiveness of different measurement methods will be assessed and recommendations made for the best protocols for measurement of the fine particle emissions.

BENEFITS: The project will provide DoD with rapid measurement procedures for organic and inorganic emissions at greatly reduced cost per analysis as well as detailed chemical compositions of major source categories by size. Assessments will be provided of the relative cost of alternative measurement strategies, ease of use, potential for use for feedback control, reliability, and speed.

TECHNICAL APPROACH AND RISKS: Two innovative techniques for rapid measurement of fine particles will be used in combination with a dilution sampler. The first is an aerosol time of flight mass spectrometer (ATOFMS) which measures the size and composition of individual articles. The second is a photoelectric Polycyclic Aromatic Hydrocarbon (PAH) detector (PED) which provides rapid measurement of the PAH-laden carbonaceous particles which dominate the emissions from combustion sources. The approach is to apply these devices in parallel with more conventional measurement techniques to establish their validity for characterizing the particle emissions from DoD sources. Multiorifice impactors (MOI) combined with chemical analysis will be used to obtain chemical characterization sufficiently detailed to close material balances on the emissions. Optical particle counters (OPC) and differential mobility analyzers (DMA) will be used to obtain detailed size distributions in order to calibrate the ATOFMS and PED. The first task will be to calibrate these methods in the laboratory. This will be followed by the evaluation of the use of the techniques for the measurement of emissions of aircraft engines and aircraft ground equipment at Hill Air Force Base and the North Island Naval Air

Depot. The techniques will be used finally for the characterization of open sources such as munitions disposal and dust from bombing ranges.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: At the end of the source test program, the techniques used in the advanced source test system will be evaluated in terms of ease of use, time of sampling to obtain data, time to analyze data, and capital and operating costs. Negotiations are in progress to produce a commercial version of the ATOFMS. The current project will have developed the calibrations necessary for producing quantitative emission measurements on DoD sources as well as a measure of the cost effectiveness of using this technology. During the course of the project, personnel from Hill Air Force Base and the Air Force Research Laboratory will evaluate the ease of transferal of the instruments to the field.

PROJECT SUMMARY

PROJECT TITLE & ID: Electrochemical Advanced Oxidation Process for Shipboard Final Purification of Filtered Black Water, Gray Water, and Bilge Water; CP-1107

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Navy

LAB: Naval Surface Warfare Center

PRINCIPAL INVESTIGATOR: Dr. Oleh Weres - Sonoma Research Company

FY 1998 FUNDS: $153K

OBJECTIVE: The overall objective of this project is to advance development of an electrochemical Advanced Oxidation Process (AOP) which will be used as a final polishing step following membrane filtration of shipboard wastewater. To comply with International Maritime Organizations Marine Pollution Convention (MARPOL) Annex V and other environmental regulations, U.S. Navy vessels require compact, energy efficient water purification technology which will allow most of the wastewaters produced on board (bilge, gray, black, etc.) to be discharged overboard following purification. Military bases and private industry generate wastewater in machine shops which must be purified before discharge to sewers. Membrane filtration does not quite achieve the degree of purification required, and a final "polishing" process is needed prior to discharge overboard. The specific objectives include producing AOP electrodes with improved service life and improved performance at low substrate concentrations, developing methods for reprocessing the electrodes, and identifying optimal operating conditions for the AOP.

BENEFITS: Once the practical feasibility of this technology has been demonstrated, the U.S. Navy will be able to decide what combination of shipboard wastewater treatment technologies to plan for. In combination with improved membrane filtration technology, electrochemical AOP will allow existing ships to be retrofitted for compliance with MARPOL Annex V and other regulations. Estimated cost savings over 20 years = $1.49B (estimate of cost to off-load untreated wastewaters). Electrochemical AOP will find broad military and industrial applications, wherever moderate concentrations of contaminants need to be removed from water at moderate cost.

TECHNICAL APPROACH AND RISKS: Existing equipment for producing small test electrodes in the laboratory will be upgraded. Apparatus permitting long term testing of the electrodes will be developed, and a correlation of service life vs. current density will be determined. Tests will be developed to evaluate the kinetics of oxidation of several substrates and determine the value of the kinetic parameter N_{OH} as it relates to different oxidation mechanisms. X-ray diffraction, scanning electron microscopy, and specialized surface analyses will be used to characterize the crystal structure, surface morphology, and surface composition of the electrodes. A standardized test of brittleness of the coated Ti-fibers will be developed.

Fiber made of the alloy Ti-6Al-4V (aerospace titanium) will be procured and evaluated for service as an electrode substrate. This alloy is expected to decrease the brittleness of the porous anodes produced, and thereby allow reprocessing of used-up electrodes at a fraction of replacement cost. Starting in FY 1998 and continuing into FY 1999 and FY 2000, the anealing steps in the electrode production process will be studied and optimized to improve the crystal structure of the resulting electrodes and minimize fiber brittleness.

Beginning in FY 1998, and extending into FY 1999, the precoating process, which is necessary to provide a useful electrode service life, will be optimized to eliminate the use of flammable organic solvents, and to decrease seepage of the precoating material into the electrocatalytic oxide coat. Also, the method of application of the oxide coat will be optimized to provide better surface coverage and better block access of electrolyte (that is, the water being treated) to the precoat and underlying metal, thereby improving the efficiency of the electrode and increasing its service life.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: Interested potential users have been identified and include the Naval Facilities Engineering Center and the Carderock Naval Surface Warfare Center; Eaton Corporation; and Showa Engineering Co. Of Tokyo, Japan. *Chemical Engineering* magazine twice described this technology, eliciting 130 requests for information. The prototype water treatment unit will very likely be carried forward to eventual commercialization.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Nonporous Fouling - Resistant Composite Nanofiltration Membranes and Membrane Separation Systems for Wastewater Treatment; CP-1108

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Navy

LAB: Naval Surface Warfare Center

PRINCIPAL INVESTIGATOR: Dr. Benny Freeman - North Carolina State University

FY 1998 FUNDS: $411K

OBJECTIVE: Fouling in available membrane is the principal problem inhibiting widespread adoption of nanofiltration/ultrafiltration to treat shipboard wastewater. All current nanofiltration/ultrafiltration membranes are finely porous and are, therefore, subject to fouling by particulates, resulting in a dramatic decline in the water flux. The objective of this research and development project is to develop a shipboard wastewater treatment system based on a novel type of fouling-resistant composite membrane module. The composite membrane will consist of an ultrathin (0.2-0.5 micrometer) nonporous, highly water-permeable block copolymer layer supported by a microporous membrane. Three candidate materials have been developed under earlier Office of Naval Research grants. In this project, development of these membranes will be completed and a systematic series of new materials which are also phase-separated block copolymers will be synthesized and characterized. The best membrane materials will be selected for scale up first to bench-scale and then to industrial-scale membrane modules. These modules will be evaluated in the laboratory in a pilot-scale system.

BENEFITS: Membrane systems can be used aboard naval vessels to purify bilgewater and graywater to allow Navy to meet current future overboard discharge limits. However, membrane fouling is the principal problem inhibiting widespread adoption of nanofiltration/ultrafiltration to treat shipboard wastewater. Novel, low-fouling membranes for graywater and bilgewater treatment will be developed. These membranes would be housed in high performance modules and together, this membrane system would result in a compact, reliable, economical shipboard wastewater treatment facility to enable Navy to meet current and forecast wastewater purification targets.

TECHNICAL APPROACH AND RISKS: Overall, the approach to overcoming the severely limited fouling resistance of conventional microporous nanofiltration and ultrafiltration membrane systems incorporates a number of innovations, the most important of which is to develop a highly water-permeable, nonporous thin-film composite membrane. The composite membrane consists of a microporous support membrane, which is an ultrafiltration or nanofiltration membrane, overcoated with an ultrathin (0.2-0.5 μm), nonporous, highly hydrophilic, rubbery block copolymer. This coating layer provides fouling resistance without significantly reducing the water flux. The Principal Investigators (PIs) will synthesize a systematic series of new heterophase membrane materials whose properties are tailored to provide better

fouling resistance than conventional membranes while maintaining or improving the flux/selectivity combinations relative to currently available materials. This research program will characterize the physical, chemical, and morphological structure of these materials as well as their water permeation, rejection, and fouling properties to develop systematic structure/property relations to guide the preparation of a new generation of advanced high performance materials for shipboard wastewater remediation.

These materials will be scaled-up to make membrane modules, and a pilot scale system will be developed to demonstrate feasibility. The risks associated with this approach include difficulties that might be encountered in the preparation of new materials, the unknown ability of these materials to be formed into thin film composite membranes, the durability of these materials in long time tests, and the ability of the materials to withstand cleaning protocols which might be used to regenerate their properties after extended use.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: At the end of the project, the researchers expect to have constructed and tested a pilot-scale nanofiltration/ultrafiltration membrane system that meets Navy needs for an efficient, reliable, low-cost shipboard water treatment system. This technology will be widely applicable to Navy and civilian ships and to onshore treatment of highly fouling waters. Collaboration will occur with Hydranautics in the module preparation work in the final phase of the project. Hydranautics is a major producer of membrane water treatment modules in the U.S. and would be a logical commercialization partner to introduce this technology to the water treatment market.

APPENDIX C
Conservation Project Summaries

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PROJECT SUMMARY

PROJECT TITLE & ID: Whale Monitoring Using IUSS; CS-48

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Office of Naval Research - Arlington, VA

PRINCIPAL INVESTIGATOR: Dr. Robert C. Gisiner

FY 1998 FUNDS: $1,265K

OBJECTIVE: The goals of this project are to continue applying U.S. Navy Integrated Undersea Surveillance System (IUSS) capabilities to monitor various species of living resources, and to contribute to the conservation and regulatory compliance goals of the U.S. Navy. The IUSS provides a unique resource to monitor the presence, distribution, movements, and relative abundance of several endangered and protected marine mammal stocks, with greatest emphasis on the large baleen whales. A close working relationship has been developed with National Oceanic and Atmospheric Administration (NOAA) and will continue to be an essential goal of the project in consideration of NOAA's role as the management and regulatory agency for protected marine life. This project will also work on the resolution of security issues concerning the IUSS database with the goal of developing accessible databases for unclassified use in education, research, and database management. Research efforts involving IUSS will also be coordinated with Navy environmental compliance efforts to enhance the Navy's leadership role in developing the highest compliance and monitoring standards for assessing and mitigating the effects of manmade noise on the marine environment.

BENEFIT: The research will enhance the U.S. Navy's ability to assess and mitigate potential impacts of its activities on marine mammals. Without the data supplied by IUSS, critical Navy activities are at serious risk of being limited due to uncertainty about the potential for environmental impact. The project greatly improves NOAA's ability to carry out its mission of conserving and managing marine mammal stocks by greatly expanding the database on little-known, wide ranging, pelagic, marine mammals like the large whales. This project will also help calibrate and expand the "tool kit" of survey methods currently used by NOAA to estimate marine mammal stocks. Without IUSS the open oceans were virtually unsurveyable due to the high logistic costs of covering these vast areas by aircraft or ship transect surveys.

TECHNICAL APPROACH AND RISKS: Emphasis will be focused on three primary tasks: (1) integration of IUSS data into Navy/NOAA databases used in assessing potential impacts of human activities on endangered and protected marine mammals, (2) creation of unclassified IUSS data access for use in education, research, resource management databases (e.g., Geographic Information System), and (3) comparative assessment of IUSS capabilities with other marine mammal monitoring and assessment tools.

The first task will be approached by continuing ongoing data collection programs for both the North Atlantic and Northeast Pacific IUSS assets. The data from these efforts will be transitioned to coordinated, collaborative efforts by the Navy and NOAA to establish centralized marine mammal databases for use in stock management (NOAA) and risk assessment decisions for environmental compliance actions (Navy and NOAA). The second task will be a logical follow-on to successful FY96-97 efforts to create mechanisms for both real-time or near real-time access to limited sets of data from decommissioned sites, as well as a process for sanitization and public release of initially classified data sets following a holding and review period by Office of Naval Intelligence (ONI). The third task will be approached through coordinated multi-methods marine mammal surveys with NOAA and university researchers. Independently collected data sets from different survey types will be compared for probability of detection, area of coverage per unit effort, and cost.

In FY97, the range of IUSS assets used in these efforts was expanded to include Fixed Distributed Systems (FDS) and Low Frequency Active Surveillance Towed Array Sonar Systems (LFA SURTASS). Risk factors include losses of IUSS, especially older Sound Surveillance System (SOSUS) arrays, as Department of Defense (DoD) downsizes, or decommissioned arrays are taken over by other activities which do not have adequate budgets to maintain cables and other expensive system hardware. Risks from losses of SOSUS assets have also been partially offset by increasing the use of other IUSS assets such as SURTASS and FDS. Security issues also remain a major concern; both from the point of view of data accessibility and publication of results, and protecting classified information relevant to primary tactical antisubmarine warfare mission of IUSS.

ACCOMPLISHMENTS: In FY97 two decommissioned SOSUS sites were reactivated: Pt. Sur (Naval Postgraduate School) and San Nicholas Island (Naval Research and Development Center). Both sites have had equipment failures (cable chafing and leakage, preamplifier damage, power supply problems) but were eventually rendered capable of delivering single hydrophone declassified data and limited classified beamformed data. Single phone data at Pt. Sur and San Nicholas Island were used to generate data on acoustic ambient noise in the area, including up-to-date quantitative measures of relative contributions of wind and weather, shipping, and biologics (mostly whales). Pt. Sur monitoring capabilities are being used in support of SERDP Project 1069 (Marine Mammal Response to Low Frequency Sound). Database collection at Whidbey Island (Pacific) and Dam Neck (Atlantic) continued with minimal interruption for the full year. Archived data tapes going back to 1993 were collected from the former Dual Use Activity Center at Naval Research Laboratory and transferred to Lockheed-Martin, Manassas, VA, for eventual transfer to ONI for analysis and sanitation.

TRANSITION: This project will provide support for the Navy's marine mammal compliance program. Collectively the marine mammal data sets are expected to form the basis for a major FY99 National Oceanographic Partnership Program and to be transitioned to an operational Navy database for fleet use in FY00. Also, first order effects of the impact of Navy operations on marine mammals will be available for NEPA analysis and for planning Navy operations. The acoustic census capability is being adopted by the National Marine Fishery Service. The SOSUS test bed and multi-array IUSS data are available for general biological and geophysical ocean science use.

PROJECT SUMMARY

PROJECT TITLE & ID: The Effects of Aircraft Overflights on Birds of Prey; CS-89

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Wright Patterson Air Force Base, OH

PRINCIPAL INVESTIGATOR: Captain Michael Carter, USAF

FY 1997 COMPLETED PROJECT

OBJECTIVE: The National Environmental Policy Act (NEPA) mandates that the Air Force assess the impact of proposed aircraft operations on the environment. The public, U.S. Fish and Wildlife Service, and the National Park Service have also raised concerns that aircraft overflights may disturb nesting birds of prey or raptors. An interim raptor dose-response model to predict the effects was developed by the Air Force Research Laboratory, Noise and Vibration Effects Branch. In cooperation with the U.S. Geological Survey Biological Resources Division, the University of Alaska - Fairbanks and Oregon State University Cooperative Fish and Wildlife Research Units, and the Air Force, the project developed a study protocol, observed raptors' responses to military overflights in the wild, and refined and validated the Air Force model.

BENEFIT: In furthering our understanding of the effects of military aircraft overflights on the environment, this project will: (1) enhance our management tools for monitoring effects, (2) obtain valuable baseline data not previously obtained (past information is anecdotal in nature), and (3) improve our capability to predict noise effects on raptors.

ACCOMPLISHMENTS: The data collection effort involved more than 2900 overflights over three field seasons and included both behavioral observations by the field crews and remote noise event monitoring by the Animal Noise Monitors (ANMs) deployed in experimental, control, and "off-river" locations. Preliminary results indicate that the birds do not abandon their nests or show other dangerous overt signs of panic, such as adults accidentally knocking chicks out of the nest scrape in their attempt to flee the aircraft overflight noise stimulus. A statistical review of the data is currently underway to define the short and long term effects of noise stress on the raptors.

TRANSITION: The validated interim raptor dose-response model will be part of the Air Force's Assessment System for Aircraft Noise (ASAN) used to provide support for NEPA and other Department of Defense (DoD) wide environmental impact analyses. Also, the prototype ANM was further developed and procured by the Air Force Air Combat Command to use in other noise effect studies on animals like the free-ranging Bighorn Sheep in Idaho and Nevada.

PROJECT SUMMARY

PROJECT TITLE & ID: Ecological Biomarkers: Monitoring Wildlife Fauna at DoD Installations; CS-244

RESEARCH CATEGORY: 6.4 Demonstration and Validation

LEAD AGENCY: Environmental Protection Agency

LAB: National Exposure Research Laboratory - Cincinnati, OH

PRINCIPAL INVESTIGATOR: Dr. Bernie Daniel

FY 1997 COMPLETED PROJECT

OBJECTIVE: The project goal was (1) to apply biomarkers (physiological, biochemical, and molecular changes in aquatic and terrestrial organisms), as tools to assess and monitor impacts of defense-associated chemical production and application, (e.g. munitions manufacturing, open detonation and open burning, decommissioning and de-arming chemical agents, fuel refining and storage, machine de-greasing wastes, and chemical by-products) on sensitive aquatic and terrestrial fauna at selected Department of Defense (DoD) facilities; (2) to establish patterns of biomarkers changes, via comparative studies of native fauna in contaminated and reference sites, that are useful for demonstrating the existence or non-existence of ecosystem level impacts from these materials; and (3) to determine which biomarkers appear to be predictive of decrements in the status of the ecological resources.

BENEFIT: The project benefits both the DoD and the public by providing baseline data to assess the ecological impact of munitions activities and providing a quantitative means to document the ecological state of the impacted area to prove or disprove cause-effect relationships between munitions by-products contamination and ecological effects.

ACCOMPLISHMENTS: Biomarkers were developed to quantify exposures to nitroaromatic munitions compounds and their by-products [e.g., 2,4,6-trinitrotoluene (TNT), 1,3,5-trinitrobenzene (TNB), 1,3-dinitrobenzene (DNB), and tetryl (TET)] which are the frequent explosives contaminants at DoD facilities. For the first time, research toxicity results on TNB demonstrate that the currently acceptable cleanup level for TNB of 0.96 ppm may be raised as much as 600-fold because TNB appears to be 600 times less hazardous than was previously calculated, using extrapolated numbers from other similar chemicals. Hence, a smaller number of TNB contaminated sites might require cleanup, and those to be remediated might not need to be cleaned up to as low a level as previously required.

TRANSITION: The scientific data was transferred to the Integrated Risk Information System (IRIS) program for use by DoD.

PROJECT SUMMARY

PROJECT TITLE & ID: Genetic Diversity Monitoring in Plants and Wildlife; CS-246

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Environmental Protection Agency

LAB: National Exposure Research Laboratory - Cincinnati, OH

PRINCIPAL INVESTIGATOR: Dr. Gregory Toth

FY 1997 COMPLETED PROJECT

OBJECTIVE: Wurtsmith Air Force Base (WAFB) in Iosco County, Michigan was selected to conduct a genetic diversity test to measure aquatic populations, primarily fish, and terrestrial populations of plants which inhabit contaminated and/or ecologically sensitive areas on the military installation. WAFB is the SERDP National Environmental Technology Test Sites (NETTS) demonstration site for *in-situ* bioremediation-based systems to cleanup soils, sediments, and groundwater contaminated with fuels, solvents, and organic mixtures.

BENEFIT: The loss of genetic diversity resulting from exposure to multiple stressors, such as habitat fragmentation/destruction or population growth, is a major concern for the conservation of native plant and wildlife populations on Department of Defense (DoD) lands. This study may provide DoD land resource managers with a scientific data driven approach to identify successes, as well as problems, with integrating the protection of ecologically-sensitive resources and aid in the design of management strategies towards eco-restoration.

ACCOMPLISHMENTS: The project used a DNA fingerprinting technique of Random Amplified Polymorphic DNA to develop indices of genetic diversity within and among populations of Black Bullhead Catfish (*Ameiurus Melas*). Researchers collected tissue samples from several populations of Black Bullhead Catfish in impacted and referenced areas to test the hypothesis that manmade stressors can act as barriers to gene flow or create bottlenecks that can lead to a loss of genetic diversity and possible population decline.

TRANSITION: A manual for evaluation of genetic diversity and ten peer-reviewed manuscripts will be delivered in FY 1998 and will be available to the scientific and user communities.

PROJECT SUMMARY

PROJECT TITLE & ID: Integration of Radiotelemetry, Remote Sensing and GIS; CS-363

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Savannah River Technology Center - Aiken, SC

PRINCIPAL INVESTIGATOR: Dr. Lynn D. Wike

FY 1997 COMPLETED PROJECT

OBJECTIVE: Parameters like habitat contours, patterns of habitat use, home range, and behavioral use of space are currently difficult and time consuming to determine but are important considerations in the evaluation of exposure and ecological risk assessment. This project will provide the capability to efficiently and accurately process this information for use in a variety of ecological analyses including: waste site characterization; ecological risk assessment; performance and success of ecosystem restorations; and habitat use of animal species of concern, such as those listed as threatened or endangered. This effort involves the integration of existing automated radiotelemetry technology with Global Positioning System (GPS), Geographic Information System, and land cover information.

BENEFIT: The capability of the radiotelemetry system to supply data density on habitat use is orders of magnitude greater than currently possible and will allow much more precise assessment of species habitat utilization and reduce the cost of acquiring such information.

ACCOMPLISHMENTS: Demonstrated small scale capability (within a hectare) to remotely monitor small animal species such as mice on or near Department of Defense (DoD) or Department of Energy (DOE) waste site facilities and analyze critical habitat use data on a labtop computer. Very small transmitters, dense underbrush, and the range of movement for the mice make this the most challenging environment to gather data. Real-time, GPS-based mapping of habitat contours for small animals will support a variety of ecological and environmental assessments. These include waste site characterization, wildlife exposure, ecological risks, and the success of ecosystem restoration.

TRANSITION: Published a final report and manuscripts of field tests, habitat contours, trapping programs, and edge effect.

PROJECT SUMMARY

PROJECT TITLE & ID: Strategic Natural Resource Management Methodology; CS-373

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: Department of Energy

LAB: Argonne National Laboratory - Argonne, IL

PRINCIPAL INVESTIGATOR: Dr. Ronald C. Sundell

FY 1997 COMPLETED PROJECT

OBJECTIVE: Current military training and testing facilities face the increased demands of base closures, advanced weapon systems requiring larger ranges, changes in tactics and doctrine, and the expanding Endangered Species Act listings. Department of Defense (DoD) resource managers and military planners must determine how to balance multiple land uses, comply with resource regulations, and assess impacts to sustainability of both the resource base and the military mission. To address this very complex issue, a computer-based, dynamic landscape modeling system was developed to help sustain natural resources and to support and facilitate military training activities by linking these objectives into a single decision support system, Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS).

BENEFIT: This project's scientific approach and resulting IDLAMS system will enable resource managers to quantify the effects of land management actions, both spatially and over time. Such an approach will reduce costs, enhance land use management responsiveness and effectiveness, disencumber military operations, enhance environmental compliance, and reduce conflicts between competing land uses. The system should also be usable at Department of Energy and other federal facilities and for resource management on federal lands. In this way, dual-use technology will be developed with broad applicability to Federal agencies.

ACCOMPLISHMENTS: A prototype decision support system was successfully demonstrated at Fort Riley, Kansas. This modular system consists of ecological, erosion, and training sub-routines, along with advanced decision support techniques combined with a core vegetation dynamics model that utilizes geographic information systems, remote sensing, and field inventory data. The installation resource manager can now: (1) identify multiple land use objectives and incorporate trade-off analysis; (2) evaluate the cost and economics of viable land use management alternatives; and (3) incorporate "what-if" scenarios into decision making.

TRANSITION: The IDLAMS Programmer's Manual, Users' Guide, Installation Guide, and Final Report will be available to DoD users in FY 1998. A workshop to discuss linkage with other SERDP and DoD Land Management modeling initiatives is planned for FY 1998.

PROJECT SUMMARY

PROJECT TITLE & ID: Threatened, Endangered, and Sensitive Resources; CS-507

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. David Tazik

FY 1998 FUNDS: $425K

OBJECTIVE: Growing numbers of threatened, endangered, and sensitive species (TES) found on military lands increasingly result in mission constraints and impediments to land acquisition, potentially leading to reduced defense readiness; lengthy and costly litigation; and criminal and civil penalties. Major objectives of this research are to continue efforts to manage TES habitats and to mitigate the effects of military-unique impacts. Specific technical objectives are to: (1) develop regional guidelines for TES habitat/community evaluation and management; (2) evaluate approaches, methodologies, and techniques to enhance conservation of TES plant population; and (3) develop conceptual models of impacts of smokes, obscurants, and Chemical Simulants on TES and make predictive assessments of effects of selected material and species.

BENEFIT: These efforts contribute substantively to a comprehensive, systematic, and integrated approach to TES management on military lands. Through this effort, the military will develop and demonstrate scientific and technical leadership in the management of TES. We will thus be better able to integrate TES considerations with military activities while avoiding mission impacts. On-going interagency coordination will yield benefits at the national, regional, and local levels.

TECHNICAL APPROACH AND RISKS: Regional TES management strategies will be developed for the Southeast Region using a plant community framework. Characterization, status, and management requirements will be defined for each plant community type and associated species based on the literature and coordination with regional experts. Management strategies will be developed that apply collectively to species with similar habitat requirements/plant community associations. TES plant populations enhancement approaches will also be evaluated for use by installation managers. We will scope the issue, evaluate specific enhancement techniques, and demonstrate specific guidelines. Small-scale field and greenhouse studies will be carried out. Impacts of smokes, obscurants and chemical simulants on plants and animals will be evaluated. Toxicity levels will be determined for selected species based on existing information and supplemented by laboratory studies as needed. Emphasis will be placed on species most likely to be affected. Up to two species will be selected for more detailed study based on this risk assessment. A conceptual model will be developed for evaluating such impacts.

ACCOMPLISHMENTS: In FY 1997, the regional habitat strategies component completed six plant community management reports, ten species profiles, and a potential military impacts report. A prototype regional handbook is planned for FY98. The TES plant component completed adaptation of a framework for prioritizing TES plants, completed field work at Fort Stewart, GA, and completed greenhouse studies at Colorado State University, Fort Collins, CO. The smokes/obscurants component integrated the DoD dispersion model into a geographic information system to develop a risk map and assessed the risk of the potential effects of fog oil from military training on the red-cockaded woodpecker.

TRANSITION: Resulting products will support the Army's environmental and endangered species management strategies and aid in efficiently meeting Army TES policies and regulatory requirements.

PROJECT SUMMARY

PROJECT TITLE & ID: Digital Terrain Modeling and Distributed Soil Erosion Simulation/ Measurement for Minimizing Environmental Impacts of Military Training; CS-752

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. Steven Warren

FY 1998 FUNDS: $500K

OBJECTIVE: The objective of this project is to develop methods and tools for prediction of the spatial and temporal distribution of runoff, soil erosion, and sediment deposition within watersheds. Soil erosion and consequent siltation of waterways have long been major environmental concerns on military installations. Most existing approaches to erosion/deposition modeling rely on lumped-parameter semi-empirical relationships developed for agricultural fields. Such approaches are unable to provide consistent results for watershed-scale runoff and erosion processes. Another primary limiting factor is the inability to accurately represent the terrain in a digital form necessary for high resolution watershed-scale erosion and sediment transport modeling. The development of new-generation technical tools to model distributed surface erosion and runoff in complex terrains is a necessity. Such tools will provide a basis for predicting the environmental impacts of military-related activities and for the optimization of land rehabilitation programs for installations.

BENEFIT: This project will improve the capability to generate accurate digital elevation models and perform topographic analyses for various terrain related applications. There will be improved capability to estimate erosion/deposition potential as an input for choosing the optimal land use management and rehabilitation programs. Modeling of erosion and deposition will assist land managers and trainers in optimizing training schedules, delineating training areas, and monitoring changes over time. The models will also assist in maximizing availability of military lands with minimal impact to natural resources, especially to soil and vegetation. The overall net result of this research will be improved land management and reduced land maintenance costs.

TECHNICAL APPROACH AND RISKS: The research project incorporates the following parallel efforts: (a) develop multivariate spline interpolation methods to support terrain modeling and processing field data; (b) completion of a distributed model of rainfall-runoff processes; (c) further development of the unit stream power theory approach to the Universal Soil Loss Equation to improve prediction of erosion, add prediction of deposition, and allow application of the model in complex topography; (d) develop a multi-dimensional application of the detachment/transport capacity theory approach to erosion and sediment prediction as contained in the Water Erosion Prediction Project (WEPP); (e) develop

vehicle-soil-climate interaction model based on field measurements of soil and hydrologic parameters; (f) collect in-stream sediment data for validation of the proposed model applications; and (g) enhance visualization techniques supporting the design and communication of dynamic erosion and sediment transport model results.

ACCOMPLISHMENTS: The Rainfall-runoff watershed model was validated and incorporated into U.S. Corps of Engineers Waterways Experiment Station's (WES) Watershed Management System for civil works properties and the unit stream power based erosion model was completed and linked to Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS). Overall the modeling efforts were enhanced by newly developed visualization techniques supporting the design and use of models of such complicated dynamic processes. The visualization methods are integrated in an open-Geographic Information System environment to facilitate fast technology transfer. These terrain modeling and erosion/deposition risk assessment techniques were successfully demonstrated on both military and non-military lands.

TRANSITION: CASC2D, an improved real-time and post-event anlaysis for rainfall-runoff processes, is an integral part of WES's Watershed Management System for civil works properties; the Unit Stream Power Erosion/Deposition (USPED) replaces a component of the Army Training and Testing Areas Carrying Capacity model and will be incorporated into land manager decision support systems such as IDLAMS. CAS2D, USPED, and Simulated Water Erosion (SIMWE) will support short- and long-range planning in the Army's Land Rehabilitation and Maintenance decision support system. These models are also an integral part of the Army's Land Management Systems demo at Fort Hood, TX, and the Upper Mississippi. Non-Department of Defense users include the Environmental Protection Agency, the National Park Service, the Agricultural Research Service, and the Natural Resources Conservation Service.

PROJECT SUMMARY

PROJECT TITLE & ID: Phased Array Acoustic Detection of Artifacts; CS-753

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. Charles Marsh

FY 1997 CANCELLED PROJECT

OBJECTIVE: Once a cultural or archeological resource site is identified it must then be assessed in order to determine its significance. Currently the costs associated with the National Register of Historic Places (NRHP) Phase II eligibility assessment of cultural and archeological resources are quite high. The objective of this work was to develop a method using acoustics to more cost effectively assess sites by avoiding the usual detailed excavation.

BENEFIT: The main benefit is to be able to non-destructively probe beneath the earth's surface to assess possible buried artifacts at a fraction of the cost associated with excavation. This would allow for the more efficient use of limited excavation resources and help speed the overall assessment of sites. In the Army alone, there are approximately 120,000 archeological sites of which only 10 percent have been assessed and the significance of the site determined. A Phase II eligibility assessment for the NRHP typically costs $10K to $30K per site. In addition, this method will be useful in the compliance with the requirements stated in the Native American Grave Protection and Repatriation Act. An additional benefit would be the rapid assessment capability employed on construction sites when an unanticipated discovery of a site occurs thus avoiding both delays and damaging artifacts. Other potential future applications include utility location and unexploded ordnance characterization.

ACCOMPLISHMENTS: This project was terminated due to lack of progress toward proof-of-principle for this technology.

TRANSITION: The research is being coordinated with the Office of Naval Research, the U.S. Army Waterways Experimental Station, and various universities and Tri-Service representatives to assess its feasibility.

PROJECT SUMMARY

PROJECT TITLE & ID: Ecological Modeling for Military Land Use Decision Support; CS-758

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Oak Ridge National Laboratory - Oak Ridge, TN

PRINCIPAL INVESTIGATOR: Dr. Virginia H. Dale

FY 1998 FUNDS: $400K

OBJECTIVE: The analyses for land use decisions require ecological models that include the spatial distribution of habitat characteristics, biological population parameters, disturbance characteristics, geophysical changes, and landscape ecology phenomena. The purpose of this research project is to develop an integrated approach that incorporates the ecological models, their input assumptions, assessment endpoints, and a user interface into a useful application for Department of Defense (DoD) land managers.

BENEFIT: This research will provide a quantitative method for assessing plans to maintain and conserve the natural resources required for DoD missions. Integrating ecological models into a spatial context for land management will result in a clearer priority for ecological information, improved decisions, and fewer specialized management programs in the future. Besides its use for management of natural resources, the proposed research is directly applicable to (1) planning for facility closures and realignment; (2) evaluating natural resource management plans; (3) supporting compliance with environmental laws such as the Endangered Species Act, the National Environmental Policy Act; and (4) developing integrated risk assessments that address cumulative effects.

TECHNICAL APPROACH AND RISKS: Development continues on ecological models to assess the impact of DoD activities on natural resources and will focus on the loss/alteration of habitat. Evaluating the risk to habitats is expressed as the probability of a change in the abundance of groups of species, habitat diversity, or landscape pattern. Model evaluation will be based on data from Fort Knox, KY and Fort McCoy, WI. The sensitivity of the models to the wide range of land management issues and data is being tested. The field tests include comparing the results of simulations to the actual field conditions. The results of the simulations will be compared with actual changes from previous activities. Data and experience from DoD and Department of Energy sites provide the basis for the models.

ACCOMPLISHMENTS: Initiated development of regional population model for the entire red-cockaded woodpecker population across the southeastern U.S. (which includes subpopulations at several military installations). Also, underway and nearing completion is the regional population model for the Karner blue butterfly. Integration with ongoing SERDP and DoD modeling efforts will continue in FY 1998.

TRANSITION: The population model of the Karner blue butterfly at Fort McCoy will be available for incorporation into the version of Integrated Dynamic Landscape Analysis and Management System being developed for Fort McCoy. Regional population modeling of the Red Cockaded Woodpecker and Karner blue butterfly will continue into FY 1998. Ecological models are available through the Oak Ridge National Laboratory web site and are submitted to widely read, peer-reviewed journals.

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced Biotelemetry for Resource Management; CS-759

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Edgewood Research, Development, and Engineering Center - Edgewood, MD

PRINCIPAL INVESTIGATOR: Dr. William S. Seegar

FY 1997 COMPLETED PROJECT

OBJECTIVE: Acquisition of accurate scientific information on free ranging organisms to fully elucidate their relationships with habitat and military land use activities is critical to the development and implementation of effective natural resource management plans. Such plans, in turn, allow the Department of Defense (DoD) to maintain biodiversity, conserve natural resources, and comply with environmental laws and regulations. This project's objective was to develop sophisticated, remote biotelemetry technology, and methodologies with which to study wildlife on military installations while minimizing disruption to military activities.

BENEFIT: This new biotelemetry capability will provide more frequent and more accurate location information than currently feasible, as well as animal behavioral information to provide state-of-the-art research data with little interference with mission activities. Such technology will enable planners and managers to meet both military and environmental requirements quickly, with accurate information, and with minimal interruption to regular base activities.

ACCOMPLISHMENTS: Prototypes of the developed GPS platform transmitter terminals (PTTs) have been successfully field-tested on captive and wild animals, yielding greatly improved accuracy of satellite transmitter location fixes. PTTs were successfully used to track the movements of Golden Eagles and Feruginous Hawks in relation to the Idaho Army National Guard Orchard military training and the Snake River Birds of Prey National Conservation areas. Also, a thorough field demonstration comparison was performed between the Global Positioning System and Doppler location estimates for sheep on a rural Maryland farm and wild ponies on Assateague Island, VA.

TRANSITION: This effort has transitioned to the DoD Legacy Resources Program. Information transfer activities include publications and technical reports available to the scientific and user community.

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Demonstration of a Risk Assessment Framework for Natural Resources on Military Training and Testing Lands; CS-1054

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Oak Ridge National Laboratory - Oak Ridge, TN

PRINCIPAL INVESTIGATOR: Dr. Glenn Suter

FY 1998 FUNDS: $430K

OBJECTIVE: Downsizing has increased demand at remaining installations for airspace, water and land area for military testing and training. Long-term suitability of training and testing areas and compliance with environmental regulations must be maintained. The objective of this effort is to develop a structured, scientifically valid risk assessment framework that can be rapidly and inexpensively applied to assess risks of single, multiple, or cumulative impacts of military training and testing activities on natural resources. This framework will incorporate physical, chemical, and biological stressors (including noise) and their direct and indirect effects, short and long term, on natural resources. Feasibility of linking Incremental Cost Analysis with the risk assessment framework will be examined.

BENEFIT: The framework will support a risk-based context which will assist Department of Defense (DoD) to better conduct training and testing activities while complying with environmental regulations, maintaining training and testing realism, and maintaining stewardship of natural resources.

TECHNICAL APPROACH AND RISKS: An Inter-Service User Advisory Group with representatives from all Services and both the testing and training communities will be formed. This group will help define the focus of the project, provide advice on prioritization of issues, and make recommendations on how to carry out technology transfer, how to prioritize planned tasks in case of budget cuts, and what tasks justify additional funding. An Interagency Scientific Advisory Group will help ensure the utility of the framework and its scientific defensibility. The Scientific Advisory Group will include scientists who are familiar with the range of relevant research that has been or is being conducted.

An initial scoping workshop will be held with the Advisory Groups to establish focus and priorities. The project will proceed by an iterative process of (1) consultation with users and DoD experts concerning a set of assessment issues, (2) summarization and organization of the consultation results, (3) framework development, and (4) review and direction by the advisory group. The results of the SERDP military training and testing assessment framework development project currently being conducted by U.S. Army Construction Engineering Research Laboratory and collaborators will serve as the first iteration of steps 1 and 2. The first iteration of the four-step process will be used to develop the first level (conceptual) framework. The later iterations will be devoted to development of a second level (implementation)

framework component for each of a series of generic types of stressors associated with training and testing. Examples could include soil and vegetation disturbance by vehicles, use of smokes and obscurants, overflights, fires, and spills of fuels. Each of these intermediate products will be designed so as to be usable by itself within the appropriate sphere of concern.

As each component is developed it will be linked into the overall framework so that effects can be combined into an overall assessment of risks to particular endpoints. The next set of iterations will be devoted to developing third level (operational) frameworks for specific training or testing activities at particular facilities. Finally, the complete framework and guidance for its implementation will be developed based on the results of the test cases and reviewed by the User Advisory Group, Scientific Advisory Group, and SERDP.

Technical risks include the scientific issues of environmental complexity and the methodological issues of designing a framework that is useful. The scientific issues are in a sense more manageable because the participants are experienced in the assessment of risks of diverse activities on complex sites and because the project is intended to identify gaps in knowledge and not to fill them all. In other words, the science of the risk assessment models and data will be state-of-the-art but will not exceed it. The methodological problems of developing a framework that is sufficiently simple in its implementation to be useful but sufficiently complex to incorporate all major issues is more difficult. In addition, the framework will need to be relevant to three services with facilities in a variety of environments and a variety of existing data, Geographic Information Systems, environmental models, etc. This problem will be addressed by using a hierarchical approach to organizing the framework, maintaining flexibility to substitute equivalent assessment tools, and regularly consulting with potential users.

ACCOMPLISHMENTS: During the first year, completed the conceptual framework and developed the options to link Incremental Cost Analysis and Risk Assessment. An interim report was submitted to SERDP.

TRANSITION: Specific DoD training or testing activities at particular facilities will be used to demonstrate risk assessment framework.

PROJECT SUMMARY

PROJECT TITLE & ID: Analysis and Assessment of Military and Non-Military Impacts on Biodiversity: Framework for Environmental Management on DoD Lands Using Mojave Desert as a Regional Case Study; CS-1055

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Environmental Protection Agency

LAB: Environmental Research Laboratory - Corvallis, OR

PRINCIPAL INVESTIGATOR: Dr. David Mouat

FY 1998 FUNDS: $550K

OBJECTIVE: The primary objective of this research is to provide Department of Defense (DoD) with techniques, tools, and training to carry out its military mission in the context of regional management of biodiversity and related ecological, stakeholder, as well as cultural and environmental resource concerns. The project develops and expands research and technology developed at Marine Corps Base (MCB) Camp Pendleton to address environmental problems at the regional scale in the western Mojave Desert (and will be coordinated with adjacent Department of Energy land holdings). It is analyzing the impacts of military and non-military stressors on patterns of biodiversity and related environmental resources and is assessing the impacts future land uses are likely to have on patterns of biodiversity. A strategic goal of the project is to enable the entire set of western Mojave installations to manage their resources unilaterally within the context of the region as a single entity as opposed to independent management without the benefit of their unity. The ultimate deliverable will be the transfer to the installations and implementation of techniques and training developed during the project.

BENEFIT: A principal benefit of the project will be a capability of the military to evaluate impacts of both DoD and non-DoD stressors (such as off-road vehicle use and suburban development) on military issues in an integrated manner. Through integrated regional ecosystem management, the military will far more effectively be able to negotiate biodiversity and other ecosystem management issues with surrounding stakeholders, ensuring minimal environmental damage while maintaining and enhancing the military mission.

TECHNICAL APPROACH AND RISKS: The project employs an integrated technical approach consisting of four components or phases. The development phase consists of the development of a Quality Assurance/Quality Control plan and a peer-reviewed experimental design, the initiation of a spatially-oriented data base management and decision support system, the organization of a military and non-military stakeholder group to identify environmental issues and human valuations of the regional ecosystem both within and outside the military context, and identification of military and non-military stressors. The basic methodology for deriving habitat information through vegetation - terrain correlation is being established. The data assembly phase consists of continued work in deriving vegetation information for habitat characterization, the development of comprehensive data bases for biotic and

abiotic resources, and the determination of key species (including the Desert Tortoise) along with their habitat requirements. Much of this work involves interaction with ongoing Legacy Program activities (for their data bases) through the U.S.Geological Survey's National Biological Resources Division and other groups. The analysis and assessments phase consists of determining habitat relationships for the Desert Tortoise and other key species, assessing management strategies for the Desert Tortoise and other key species, assessing the "sweep" potential for using certain key species (e.g., the Desert Tortoise) for deriving habitat and management strategies for other species, and evaluating the effects of existing land uses and other stressors on habitat and biodiversity. The modeling and products delivery phase involves modeling the effects of future land use scenarios on stressors and on the likely impacts on biodiversity and related environmental resources. It also involves reporting and publication coordination, stakeholder briefings, and technology transfer activities. A number of technical risks are associated with the proposed activities. Some involve the necessity of having qualified individuals at the installations to implement the output products produced. This risk also involves successful integration of the installations themselves. In addition, it is imperative that appropriate questions and issues are asked and addressed. Possible incompatibility of disparate databases is another potential risk.

ACCOMPLISHMENTS: During the first year, the stakeholder group was identified and study area was defined. Progress is being made in vegetation and terrain mapping. Satellite imagery has been acquired, and along with previously acquired airborne videography, is being analyzed.

TRANSITION: Results of the project will further provide the military with techniques, tools, and training to evaluate the impacts of future development and land uses on the environment and to be able to coordinate responses. Technology transfer activities will be initiated to implement the framework developed for MCB Camp Pendleton at MCAGCC 29 Palms.

PROJECT SUMMARY

PROJECT TITLE & ID: Marine Mammal Responses to Low Frequency Sound; CS-1069

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Office of Naval Research - Arlington, VA

PRINCIPAL INVESTIGATOR: Dr. Robert C. Gisiner

FY 1998 FUNDS: $800K

OBJECTIVE: The development of state-of-the-art monitoring and mitigation capabilities for assessing the impacts of manmade low frequency sound on the marine environment, with emphasis on marine mammals, is the purpose of this project. Marine mammals are protected as a group by special legislation, the Marine Mammal Protection Act (MMPA). In addition, many marine mammals are listed under the Endangered Species Act because their numbers have been severely reduced by hunting and habitat destruction. We do not currently have an adequate understanding of the effects of manmade sound on the environment, but we anticipate that large whales which emit low frequency sound for sensing and communication, and other marine mammals which dive into the deep sound conducting channel, are most vulnerable to exposure to manmade, low frequency sound sources. This program aims to collect data on this question while exploring new technology that will better enable us to monitor the marine environment.

BENEFIT: There are two areas of benefit from this project. One is the acquisition of data on the effects of manmade low frequency sound on marine mammals. There is relatively little data on this subject and therefore little in the way of regulatory guidelines or standardized assessment and mitigation procedures. The second area of benefit covers the development of technology to improve detection and monitoring of marine mammals. Not only are these developments of critical interest to the Navy, but they are also applicable to a variety of commercial and recreational activities that emit sound and, therefore, might have an impact on marine mammals.

TECHNICAL APPROACH AND RISKS: The technical approach is based on the data required to assess the impact of manmade sound on marine mammals. One aspect of this process is measurement of received sound levels around the sound source to calibrate the effectiveness of planning models of transmission loss. Acoustic monitors may be bottom-mounted (pop-up buoys), moored, drift, attached to a mobile platform like a ship, or attached to marine mammals. A second aspect of the process involves assessing the abundance and distribution of marine mammals around the sound source. This is accomplished through aerial and ship-based surveys of the site using both visual and acoustic monitoring. The third aspect of the process involves assessing the response of marine mammals to the sound received from the source. Approaches can include attaching remote sensors to the animals themselves to monitor movements, heart rate, vocal activity, and other indices of response. Follow-up studies of long term effects will make use of a pool of individually identifiable individuals obtained from ship-based photo-

identification. Risks are primarily associated with climatic variability that might make comparison between years difficult and might also prevent completion of sampling and experiments due to bad weather.

ACCOMPLISHMENTS: Spring elephant seal translocations completed. Completed preliminary analysis of California aerial survey data.

TRANSITION: The results of this project will be widely disseminated to the scientific and using community and should play a key role in the formulation of future Department of Defense/Navy policy on this issue.

PROJECT SUMMARY

PROJECT TITLE & ID: Information Technology Tools for Assessment and Prediction of the Potential Effects of Military Noise on Marine Mammals; CS-1082

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Navy

LAB: SPAWARSYSCEN - San Diego, CA

PRINCIPAL INVESTIGATOR: Dr. David Helweg

FY 1998 FUNDS: $355K

OBJECTIVE: Currently, the Department of Defense (DoD) lacks scientifically defensible tools concerning the safe operation of many of their training and testing systems [e.g., Low Frequency Active (LFA) sonar and Shipshock] in the presence of marine mammals. Although there is increasing concern over the effects on marine mammals of man made sound in the oceans, there is very little direct information about what sound frequency-intensity combinations damage marine mammal hearing. Our broad objective is to transition information about effects of DoD sound types on marine mammal auditory anatomy and acoustic ecology to predictive models and mitigation tools. This effort responds directly to the DoD capability to comply with the National Environmental Policy Act requirements and will contribute directly to answering the National Research Council's Research Needs related to the effect of low-frequency sound on marine mammals (1994).

BENEFIT: DoD lacks scientifically defensible positions concerning the safe use of LFA and Shipshock testing in the presence of marine mammals. These research tasks will provide information that feed directly into the assessment and prediction of military noise effects on marine mammals.

TECHNICAL APPROACH AND RISKS: This project consists of three inter-related tasks. Task 1 consists of otopathological analyses of marine mammal ears. Task 2 consists of otopathological analyses of baleen whale ears, the results of which will motivate development of a biomimetic model of baleen whale auditory responsiveness to DoD sound types. Task 3 will utilize predictions about sensitivity generated in Task 2, plus statistical sampling models and acoustical classification algorithms, to develop a capability to automate the use of the U.S. Navy's Integrated Undersea Surveillance System (IUSS) for mapping the distribution of whales in the Southern California region. Task 3 is coordinated with other related SERDP efforts on the potential effect of anthropogenic sound on marine mammals.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: The results will provide information that will feed directly into the assessment and prediction of military noise effects on marine mammals.

PROJECT SUMMARY

PROJECT TITLE & ID: Assessment of Training Noise Impacts on the Red-Cockaded Woodpecker; CS-1083

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. Larry Pater

FY 1998 FUNDS: $350K

OBJECTIVE: The objective is to determine the impact of certain types of training noise on the endangered red-cockaded woodpecker (RCW). The project will also develop and make available cost-effective techniques that installations and other researchers can use to evaluate and monitor effects of military noise on animal species. These techniques include the capability to characterize noise stimuli, document physiological and behavioral responses, and determine resulting population effects due to military noise. The proposed research will provide information required to assess and manage risk to both military training capability and the endangered RCW and will provide factual basis for mitigation and management protocols and guidelines.

BENEFIT: This project will provide the data required to address RCW regulatory issues, to guide effective impact management on Threatened and Endangered Species (TES) populations, and to preserve TES populations. This will help to alleviate impacts on training capability, to avoid the need to acquire additional training land, and to minimize litigation and delays.

TECHNICAL APPROACH AND RISKS: The research paradigm is that proximate effects can be linked to individual fitness, which in turn can be linked to population effects. The proximate response measures that will be used are flush from nest cavity, feeding of young in nest, and feeding behavior (non-nesting). Field studies of the in-situ response of the animal to the measured noise events will be used to determine dose-response relationships. Individual fitness measures will include number of young fledged per nest, adult turnover, group size, and mating success. These demographic parameters will be correlated with measured noise levels. A second strategy to assess noise effects on individual fitness will be to correlate historic demographic data with estimated noise levels, using available training noise models. The empirical data from these efforts will be integrated into leveraged RCW population models to assess noise impacts at the population level. Four noise types will be considered: artillery noise, small arms noise, helicopter noise, and maneuver noise. The latter is a mix of the other three types.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: Research results will transition to Army land management decision support tools.

PROJECT SUMMARY

PROJECT TITLE & ID: Freshwater Decision Makers' Information Needs; CS-1086

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: General Services Administration

LAB: N/A

PRINCIPAL INVESTIGATOR: Dr. Chris Bernabo - Science & Policy Associates, Inc.

FY 1997 COMPLETED PROJECT

OBJECTIVE: This project will enhance communication between researchers and decision makers on freshwater issues, and encourage the use of scientific information on water resources that serves the needs of the Department of Defense (DoD) manages and policy makers. The project will identify the key issues of decision makers through interviews and focus groups. Research guidance will be developed to address those needs. The priority issues will be identified based on scientific understanding tailored to address DoD's environmental management and policy goals. In addition, a small group of water resource experts will be used to review conclusions and provide feedback. Along with DoD/SERDP, several organizations have been involved in the project, including the National Science Foundation, the Environmental Protection Agency, and the Electric Power Research Institute.

BENEFIT: This project will (1) improve DoD's use of scientific information in environmental policy and management decisions, (2) provide guidance for research that addresses DoD's environmental information needs, and (3) broaden DoD's understanding of freshwater research results and their value.

ACCOMPLISHMENTS: Organized and convened a meeting of the multi-agency steering committee; prepared background documents and presentation materials; and reviewed the results of preliminary interviews with national-level decision makers.

TRANSITION: In 1998, the project will refine framework of decision makers' needs and policy-relevant science questions and present results and conclusions to project sponsors and other stakeholders.

PROJECT SUMMARY

PROJECT TITLE & ID: Land Management Systems; CS-1088

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Waterways Experiment Station - Vicksburg, MS

PRINCIPAL INVESTIGATOR: Dr. Jeffrey Holland

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective of this project was to define where landscape and ecosystem management modeling and simulation (M&S) is in terms of data, data management, models, modeling theory, and technology; and support the identification of a course for future investments, both by SERDP and other services, activities, and agencies. This proposal is intended to supplement a larger Corp of Engineers initiative in land management modeling and simulation and decision support systems. This initiative involves the following tasks. This project targets task c.

a. Examine the various protocols for modeling and simulation data.
b. Develop a land management M&S catalog or compendium of efforts, technologies, and techniques that will support integrated land management M&S.
c. Determine the strengths and weaknesses of existing M&S efforts and what strengths need to be exploited and weaknesses addressed to insure an integrated future for land management decision support.
d. Develop a design and structure for future land management M&S capability.
e. Identify and develop the M&S linkages needed to insure effective land management decision support capabilities of the future.

BENEFIT: Within the Conservation thrust area, SERDP has supported many excellent efforts to advance this type technology. The examination of strengths and weaknesses of existing land-scape modeling and simulation capability will insure that the efforts of the Department of Defense (DoD), including SERDP, and other agencies and activities result in the best technology infusion for land managers.

ACCOMPLISHMENTS: This project started late in FY 1997. To date it has completed an initial assessment of current and developing capabilities associated with DoD installation land management modeling and simulation.

TRANSITION: In 1998, a demonstration of the required characteristics of the future DoD land management decision support system is planned.

PROJECT SUMMARY

PROJECT TITLE & ID: Error and Uncertainty Analysis for Ecological Modeling and Simulation; CS-1096

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. George Gertner - University of Illinois

FY 1998 FUNDS: $575K

OBJECTIVE: Taking into account the growing importance of simulation modeling in natural and cultural resource assessment and management, the Department of Defense (DoD) need for a comprehensive framework for analyzing uncertainty of simulation results is apparent. Most values employed in simulation modeling are estimates of the true parameters and, therefore, have an associated uncertainty. Error budgets can be used to assess the quality of the overall simulation system. Although progress has been made in the areas of uncertainty analysis and error budgets, there is a need to develop the statistical and computational tools. These tools are needed to enable model users to jointly assess and quantify the sources and magnitude of input errors and/or expense for the array of large scale DoD simulation models employed in resource assessment and management.

BENEFIT: This project will provide the rationale to account for the effect of different sources of error on the uncertainty of predictions made through models, and also provide the rationale for efficiently reducing the uncertainty. This methodology will be relevant to all users of ecological and environmental models.

TECHNICAL APPROACH AND RISKS: The proposed analytical framework will be made available as a user-friendly interactive software package and provide model users with the means to assess and exert control over the quality of the simulation results. In parallel, the project will apply this methodology to a monitoring-modeling system employed by the military for assessment and/or management of natural and cultural resources at one military installation. Two primary candidate models are the Army Training and Testing Area Carrying and/or the Terrain Modeling and Soil Erosion Simulation.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: This capability will provide the necessary quality control/assurance mechanisms to support DoD decision support systems regarding natural and cultural resources.

PROJECT SUMMARY

PROJECT TITLE & ID: Emerging and Contemporary Technologies in Remote Sensing for Ecosystem Assessment and Change Detection on Military Reservations; CS-1098

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. ARMY

LAB: Topographic Engineering Center - Fort Belvoir, VA

PRINCIPAL INVESTIGATOR: Mr. Randall Karalus

FY 1998 FUNDS: $1,000K

OBJECTIVE: This project will be conducted in coordination with the University of Nevada at Reno and Utah State University. The objectives of this project are to: stratify the landscapes of individual military ranges using contemporary and emerging remote sensing technologies; identify the fundamental vegetation and soil attributes of military ranges as they relate to plant succession; establish ecosystem response and recovery in relation to disturbance (land use) through retrospective studies with spatially-explicit spectral-based indices; identify the spatial, spectral, and temporal attributes of remote sensing systems necessary to identify ecotones and to distinguish along environmental and disturbance gradients; and lastly, develop methods for scaling indices between coarse and fine resolution imagery.

BENEFIT: The project will provide Department of Defense (DoD) managers with efficient tools, models, and techniques to better characterize and quantify the carrying capacity of land resources to support military training and testing. Being able to estimate ecosystem sustainability, managers can predict the impacts of land-based usage, understand the risk associated with use, and analyze decisions to provide training flexibility versus environmental or ecological damage. This includes: models for change detection of land use; methods for scale transitions; relationships between hierarchical scheme of spectral and spatial resolution to ecotone/biological thresholds/degradation; and a better understanding of ecosystem response and recovery in relation to disturbance (land use).

TECHNICAL APPROACH AND RISKS: The technical approach for this project is essentially a composite of: (1) mapping the installation; (2) correlating the fundamental attributes of disturbance and plant succession; (3) analyzing, retrospectively, the ecological history of each installation in relation to land use, and; (4) assessing high resolution systems to identify the sensor attributes necessary to monitor changes in plant species composition along disturbance gradients and plant succession stages.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: The results will provide DoD installation resource managers with efficient tools, models, and techniques to better characterize and quantify the carrying capacity of land resources to support military training and testing. DoD demonstration sites have been chosen.

PROJECT SUMMARY

PROJECT TITLE & ID: Predicting the Effects of Ecosystem Fragmentation and Restoration: Management Models for Animal Populations; CS-1100

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Dr. Thomas Sisk - Northern Arizona University

FY 1998 FUNDS: $180K

OBJECTIVE: An improved understanding of the effects of ecosystem fragmentation is required for better integration of Department of Defense (DoD) land management and training objectives and for maximizing the benefits associated with land rehabilitation and habitat restoration. The detrimental effects of habitat fragmentation on animal populations are widely documented. In contrast, the development of practical tools to predict the effects of fragmentation and design appropriate mitigation efforts has progressed slowly. DoD training and related activities on and adjacent to military lands often contribute to fragmentation and affect species of special concern, including threatened and endangered species. This project proposes to develop species-specific models that predict the responses of mobile animal species in heterogeneous landscapes. Modeling efforts will build on connections between life history characteristics and the responses of mobile animals to habitat fragmentation and restoration. Field research will permit parameterization of models and testing of model predictions, leading to refinement of the conceptual approach. The primary foci are the ponderosa pine forests and riparian habitats on military lands. These two habitat types are widespread throughout the U.S. and currently the subject of great management debate.

BENEFIT: The project will link field and remotely sensed data in validated landscape models that will permit comparison of alternative land use strategies on wildlife species of management concern. Extensive field testing of model predictions in different environments will permit evaluations of model effectiveness in forecasting the responses of a wide range of species to landscape-scale alterations in forested and riparian habitats. The model will operate in the ARC and ArcView geographic information system environments. Through manipulation of habitat maps, the Effective Area Model (EAM) will be capable of predicting the effects of alternative landscape modifications -- habitat fragmentation due to operational activities, or habitat restoration resulting from rehabilitation or mitigation efforts -- on a wide range of animal species.

TECHNICAL APPROACH AND RISKS: The project is a cooperative effort involving Northern Arizona University (NAU), Colorado State University (CSU), the Ponderosa Pine Ecosystem Restoration Project, the Semi-Arid Land Surface Atmosphere Project (SALSA), Camp Navajo (U.S. Army and Arizona Army National Guard), and Ft. Huachuca (U.S. Army). The project links three areas of investigation: acquisition of ecological field data on the responses of animals to habitat fragmentation; the

mapping of animal habitats in three dimensions and at scales relevant to habitat management; and the linking of empirical ecological data and spatially explicit habitat information in a management-oriented model, the EAM. Field data will be collected along transects running orthogonal to habitat edges and will quantify population density and other relevant parameters at different distances from habitat edges. Statistical and mathematical approaches will permit characterization of species' responses. Field research will target species of special interest to managers, such as sensitive, threatened and endangered species, but it also will include a broad range of species that might influence the populations species of management concern through, for example, competition or predation. Habitat mapping will rely on remotely-sensed data and field measurements. LANDSAT imagery and aerial photography will permit delineation of the spatial extent, shape, and juxtaposition of habitat patches. Important structural attributes will be explored through the use of Synthetic Aperture Radar, aerial photography, and field measurements. Overlay of pertinent data sets in a Geographical Information System environment will allow integration of habitat attributes and identification of floristically and structurally distinct habitat types, as well as the edges that separate different habitat patches. Completed habitat maps will serve as input to the EAM. The modeling approach will project species-specific edge responses, measured in the field and characterized mathematically, onto the spatially explicit habitat maps, weighting each habitat patch according to its area and the influence of the surrounding habitat on species abundance and demographic variables.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: The project results will be provided to land managers who will link field and remotely sensed data in validated landscape models that will permit comparison of alternative land use strategies on wildlife species of management concern.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Units of Measure for Training and Testing Area Carrying Capacity Estimation; CS-1102

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Construction Engineering Research Laboratories - Champaign, IL

PRINCIPAL INVESTIGATOR: Mr. Alan Anderson

FY 1998 FUNDS: $300K

OBJECTIVE: Department of Defense (DoD) training and testing land carrying capacity is the ability of specific land parcels to accommodate military training exercises and mission activity. In 1995, the Army funded a proof-of-concept study to develop a methodology for estimating the operation and support costs of using land for the training of ground forces. The methodology known as Army Training and Testing Area Carrying Capacity (ATTACC) consisted of three components: training, environment, and economic. The training component involves specifying the training load based on type and number of units, vehicles, and training events. The environmental component involves estimating changes in the land condition. The economic component involves estimating the cost of land rehabilitation and maintenance. This project proposes to significantly improve the methodology as an installation management tool to better predict the environmental consequences of military training activities. The focus of this project is to develop quantitative units of measure (such as erosion and species composition on land) to estimate training and testing land carrying capacity, extend the spatial and temporal scale of the methodology to include individual training areas and changes in training and land condition throughout the year, and validate the improved methodology.

BENEFIT: By providing an improved methodology, mission impacts can more accurately be matched to the ecological capability of military lands to support those activities resulting in decreased land maintenance costs, maintaining realistic training conditions, and increasing land use capacities.

TECHNICAL APPROACH AND RISKS: In the existing ATTACC methodology, erosion status is estimated using the Revised Universal Soil Loss Equation (RUSLE). Because the RUSLE equation was developed for agricultural lands, it does not account for complex topography that is typical of military lands. The unit stream power approach for estimating the topographic factor of RUSLE will be used to account for complex topography typical of military lands. This project will extend the current ATTACC methodology to include wind erosion in addition to water erosion. Existing wind erosion models will be evaluated to determine which is most applicable to military lands based on data requirements and model assumptions. The results from the existing SERDP project on Terrain Modeling and Soil Erosion are being used to improve estimates of land condition and can be extended to off-site impacts (sedimentation and water quality). It will also extend the ATTACC methodology to include plant species composition

as a measure of land condition. To incorporate species composition into the ATTACC model, the Ecological Dynamics Simulation (EDYS) model will be utilized.

The EDYS model is a process-based model that predicts changes in species composition that naturally occur over time and in response to natural disturbances. A military impacts sub-model will be developed for the EDYS model. The military impacts sub-model will translate training/testing activities into changes in soil and vegetation processes. Existing DoD impact studies will be used to estimate the primary impacts of military activities on soil and vegetation processes. The ATTACC methodology will also be extended to account for climatic variation throughout a year. Components of the ATTACC model will be modified to incorporate time varying climatic factors. Temporal differences in mission impacts on the vegetative cover factor will be estimated from existing DoD impact studies.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: This project will feed into the current ATTACC methodology to include wind erosion, land condition, and plant species composition.

PROJECT SUMMARY

PROJECT TITLE & ID: Identify Resilient Plant Characteristics and Develop a Wear Resistant Plant Cultivar for Use on Military Training Lands; CS-1103

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: U.S. Army Cold Regions Research and Engineering Laboratory - Hanover, NH

PRINCIPAL INVESTIGATOR: Mr. Antonio Palazzo

FY 1998 FUNDS: $200K

OBJECTIVE: Wear-resistant plants are needed to mitigate environmental impacts and improve the use of Department of Defense (DoD) training lands. There is little knowledge on the relationships between military training and plant injury, regrowth, and wear resistance. Plant and soil data will be combined which will allow land users to make knowledgeable choices concerning plant selection and site-rehabilitation procedures to reduce soil erosion. Resilient plants have been previously identified at several DoD/Army training sites using field surveys. Several resilient plant clones have also been collected from Yakima Training Center, Fort Carson, and Logan, UT. This project intends to use these collections and other plants to breed new more resilient cultivars. A second objective is to conduct field and greenhouse studies to quantify the degree of compaction that occurs during training and relate soil condition to root injury in plants with known resilience. This effort leverages on existing DoD Tri-Service Environmental Quality Research and Development on plant selection and plant characteristics to attain an optimal use of land capacity to sustain military training and testing.

BENEFIT: This project will provide DoD guidance for mitigation methods and will provide more resilient plant species that will help to increase training opportunities on existing training areas. This guidance will assist land managers and trainers in making choices on training schedules and in estimating cost and time requirements for maintaining military readiness.

TECHNICAL APPROACH AND RISKS: The activities of the proposed research are to identify and develop training-resilient plant cultivars and conduct field and greenhouse studies to quantify the degree of soil compaction that occurs during training, relating this soil condition to root injury in plants with known resilience.

For plant breeding, the approach follows:

1. A broad genetic base of native and naturalized plant materials has been assembled and established in space-planted breeding nurseries and seeded evaluation trials at Fort Carson, the Yakima Training Center, and Logan, UT. Individual plants and seeded plots in these trials are being evaluated for

seedling vigor, tiller and rhizome development, resistance to drought and plant pests, early spring growth, and vegetative vigor.

2. Superior clonal and progeny lines will be selected from breeding nurseries and established in plantings near Logan, UT, and on selected sites at Yakima and Fort Carson to initiate the second breeding cycle. Accessions and cultivars selected on the basis of results from evaluation trials will be included in larger-scale plantings, primarily in mixtures of two or more species. Performance of plant materials in new evaluation trials will be determined in seeded plots subjected to disturbances by army vehicles.
3. Plant materials in the second-cycle breeding nurseries will be evaluated more intensively than during the first cycle. We will evaluate these plants using available Random Amplified Polymorphic DNA (RAPD) technology developed under the BT-25 genetic marker program along with more traditional screening methods. More emphasis will be placed on seedling vigor under imposed stress, rapidity and extent of tiller and rhizome development, reduced seed dormancy and more rapid seed germination, and responses to abiotic and biotic stress.
4. Clones will be selected from the second-cycle breeding nurseries on the basis of parental and progeny performance and included in crossing blocks to produce seed of experimental strains.
5. Experimental strains then will be subjected to seeded trials under a range of environmental conditions to identify those for release as improved cultivars. These new cultivars will be used along with those plant materials previously identified in the seeded evaluation trials to provide a resilient and stable vegetative cover.

For soil compaction, the approach follows:

1. Use cone penetrometers to assess the degree of soil compaction that occurs after training exercises on several training lands.
2. Evaluate the degree of root injury occurring in the field as a result of soil compaction along with any resulting harmful effects on plants' ability to regrow and adapt. Use field data to design and conduct greenhouse studies on interaction of root growth and soil compaction. Relate training intensity to plant injury.
3. Conduct new greenhouse studies to further document the effects of soil compaction on root growth.
4. Conduct field studies to evaluate root growth of newly-developed cultivar in soil-compacted conditions.
5. Use results to determine land rehabilitation requirements.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: These results will be integrated into land management decision support tools to provide DoD land managers the necessary guidance for mitigation methods and more resilient plant species that will help to increase training opportunities on existing training areas.

APPENDIX D
Pollution Prevention Project Summaries

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PROJECT SUMMARY

PROJECT TITLE & ID: DoD/DOE Clean Agile Manufacturing of Energetics (CAME); PP-63

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Office of Naval Research - Arlington, VA

PRINCIPAL INVESTIGATOR: Dr. Richard Miller

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective of this program was to develop energetic materials and processing technologies to provide concepts for reconfiguring existing propellants, explosives, and pyrotechnics (PEP) life-cycle facilities into clean, agile operations that will function economically with total life-cycle wastes reduced by up to 90 percent from a 1992 baseline. This project developed new chemicals and processes to enable pollution prevention simultaneously with providing increased PEP energy and lower production costs.

BENEFIT: By 1998 this project will provide automated tools for PEP life-cycle analysis and a conceptual approach, based on these tools, for reconfiguring existing PEP factories to reduce hazardous wastes by a factor of ten, almost twice the 1999 national goal for pollution prevention. This will mitigate price increases of future PEP products due to cost of complying with more stringent future environmental regulations. Satisfying regulations will help curtail factory shutdowns or unscheduled retirement of ordnance systems.

ACCOMPLISHMENTS:

1. The Batch Design Kit (BDK) work at Massachusetts Institute of Technology (MIT) was completed and turned over to Naval Surface Warfare Center - Indian Head Division (NSWC-IHD) which has begun using it to facilitate preparation of Standard Operating Procedures (SOPs).
2. Computational process design tools and an injection loader at the NSWC-IHD, Yorktown Detachment were used to demonstrate reduction of warhead loading wastes by 80 percent. These computational design tools are currently being used by Naval Sea Systems Command (NAVSEA) (PMO-407) in their Explosive Standoff Minefield Breecher (ESMB) product improvement program co-funded by Navy MANTECH to develop an injection loading process for plastic sub-munitions. If successful, this effort will save as much as $70 million over the planned procurement time frame compared to the baseline technology.
3. Aerojet has reduced to practice an environmentally sound method of synthesis of monomers which are the precursors to AMMO and BAMO thermoplastic elastomers (TPEs). The production of (energetic) polymeric binders does not use any ozone depleting substances. Water and carbon dioxide are used in place of isocyanates.

TRANSITION: The products and tools developed from this project have been successfully transitioned to the NAVSEA Green Energetics Manufacturing (GEM) Program Affordability Initiative which will develop and evaluate TPE propellants for a gun-launched rocket to be fired from a Navy 5-inch gun. Other transitional products are noted in the accomplishments.

PROJECT SUMMARY

PROJECT TITLE & ID: Organic Protective Coatings and Application Technology; PP-65

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center Aircraft Division - Patuxent River, MD

PRINCIPAL INVESTIGATOR: Dr. Kevin Kovaleski

FY 1998 FUNDS: $330K

OBJECTIVE: The objective is to develop high performance, non-toxic, low volatile organic compound (VOC) content coatings which provide protection against environmental degradation as well as passive countermeasures for Navy aircraft and weapon systems. The Navy currently uses numerous coatings due to their diverse functions, variety of substrate applications, and severe operational environment. The toxic inhibitors (i.e., lead, chromates, etc.) and high VOC contents of these coatings are released during painting operations as organic and toxic air emissions. Federal, state, and local environmental agencies restrict these hazardous emissions through regulations such as the Clean Air and Water Acts, and local Air Quality Management District rules. Chief of Naval Operations (CNO) directives require significant reductions in the Navy's hazardous waste generation of which painting operations are a major contributor. Therefore, it is necessary to develop new high performance coatings which meet environmental restrictions and allow the Navy to continue painting operations.

BENEFIT: The development of non-toxic, VOC compliant coatings will enable the Navy to meet current and future environmental regulations and will reduce the total amount of hazardous waste generated by painting operations. Furthermore, these new materials will eliminate the need for installation of extremely expensive control equipment (i.e., $1M-5M per spray booth for VOC emission control and multi-filter systems for hazardous air pollutants). This effort is in direct support of Navy and Department of Defense hazardous waste minimization policies/directives.

TECHNICAL APPROACH AND RISKS: A full spectrum approach for reducing the VOC and air toxic emissions from protective coatings is being pursued. Research in reactive monomers & dilutants (low VOC polymer technology) is being used to produce low VOC binder systems for future aircraft coatings. New waterborne resin technology has allowed for the development of high performance topcoats. Also, several experimental compliant materials (a non-Cr, low VOC self-priming topcoat; one-component lacquers, non-toxic inhibitors, powder coats, and electrocoatings) will be investigated for this program. [The topcoat has been authorized for Navy use and is currently at Naval Depots (NADEPs).] One component urethane coatings are being developed to replace high VOC lacquers for touch-up applications. Non-toxic inhibited primers and sealant coatings will replace current chromate materials. These materials are being optimized, service evaluated and then implemented for Navy use. Finally, conventional air spray which has a low transfer efficiency of 28 percent will be prohibited by the Clean Air Act (CAA). Therefore, high transfer

efficient application equipment such as air-assisted, airless, electrostatic, and high volume low pressure (HVLP), was evaluated for painting operations. (HVLP is currently at the NADEPs.)

ACCOMPLISHMENTS:

1. Laboratory testing of the waterborne topcoat is complete and arrangements were made for a demonstration on an H-46 helicopter at NADEP Cherry Point. The specification will be revised to allow for changes in resin technology, i.e., a new modification will not be necessary each time a lower VOC system is introduced.
2. The newest versions of the zero-VOC topcoat are currently being evaluated. The short-term tests show that the majority of the problems stated in June, 1997 have been solved; however, flexibility values are still too low.
3. Service evaluations of Courtaulds non-chromate inhibited sealants continue at NADEPs in Cherry Point and North Island. The non-chromate sealants are proving to be satisfactory replacements for the chromate sealants.

TRANSITION: The self-priming topcoat has been authorized for Navy use. This topcoat and HVLP are currently being implemented at Navy NADEPs. The Environmental Security Technology Certification Program (ESTCP) will fund a demonstration validation of the zero-VOC topcoat at the NADEPs and Warner-Robins Air Logistics Center. This technology is being coordinated with commercial aerospace, coatings, and equipment manufacturers to insure product availability for implementation.

PROJECT SUMMARY

PROJECT TITLE & ID: Aircraft Maintenance Chromium Replacement; PP-66

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center Aircraft Division - Patuxent River, MD

PRINCIPAL INVESTIGATOR: Dr. Catherine Rice

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective was to replace chromates (Cr) currently used in aerospace materials and processes on Navy aircraft (A/C) and weapon systems. Chromium VI is a carcinogen and Federal, state, and local agencies have issued regulations that limit or prohibit the use of chromate materials. Specifically, the 1990 Clean Air Act Amendment electrolytic chromium National Emission Standard for Hazardous Air Pollution (NESHAP) and the San Diego Air Quality Management District electrolytic chromium rule restrict the emissions from these processes beginning in 1994. In addition, Service directives require significant reductions in hazardous waste generation, of which production and depot level maintenance chromate processes such as chromic acid anodizing and chrome containing materials are major contributors. To comply with these regulations while maintaining A/C operational readiness, chrome-free alternatives have to be developed and transitioned to fleet use.

BENEFIT: The elimination of chromic acid anodizing, chromate conversion coatings, and chromate adhesive bonding material significantly reduces the total amount of chromium emitted from Navy operations. Replacement of chromic acid anodizing also eliminates the need for expensive emission control equipment, estimated at $700K capital and $250K annual operating costs per Depot facility. Furthermore, these alternatives reduce the amount of chromium disposal from Navy operations (estimated at 12 tons/year per facility). This technology is being coordinated with commercial aerospace, chemical and equipment manufacturers.

ACCOMPLISHMENTS: The sulfuric/boric acid anodizing (SBAA) process for pretreatment of aluminum was successfully demonstrated on an S-3 aircraft at the Naval Aviation Depot at North Island, CA. For titanium adhesive bond treatment, the Boeing and Chemat sol-gels appears to show promise with the epoxy adhesive.

TRANSITION PLAN: The sulfuric/boric acid anodizing (SBAA) process developed as alternative to chromic acid anodizing (CAA) for prepainting applications has successfully transitioned to the fleet through the Naval Aviation Pollution Prevention Demonstration/Validation Program (W2210) sponsored by the Chief of Naval Operations, N-45. Sol-gel adhesive bonding primers will continue undergoing evaluation under Navy research and development funding.

PROJECT SUMMARY

PROJECT TITLE & ID: Solvent Substitution and Low VOC Cleaners; PP-67

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center Aircraft Division - Patuxent River, MD

PRINCIPAL INVESTIGATOR: Mr. Philip Bevilacqua

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective was to develop low volatile organic compound (VOC) content and non hazardous air pollutant (HAP) maintenance products for use on Navy aircraft (A/C) and weapon platforms. Naval aviation depot aircraft maintenance operations have been identified as major contributors to the hazardous waste generated by the Navy. Currently, solvents classified as HAPs, such as methyl ethyl ketone (MEK), are used for surface pre-cleaning prior to painting and for purging paint spray equipment. Chemical paint strippers contain methylene chloride, which was banned from use in stripping operations in 1997. Aircraft cleaning and corrosion preventive compounds used in routine aircraft maintenance operations are high in VOCs. The EPA Clean Air Act and local Air Quality Management District rules restrict the use and disposal of these hazardous materials. Therefore, non-HAP and low-VOC alternative maintenance products that meet regulatory criteria while maintaining aircraft operational readiness need to be developed and implemented.

BENEFIT: The development of non-HAP, low-VOC maintenance chemicals will significantly reduce the total amount of hazardous materials generated by Navy maintenance facilities. This is particularly important considering the cost of the aircraft and weapon systems as well as the severely deleterious environment in which the Navy operates. This effort is being coordinated with commercial aerospace, chemical, and equipment manufacturers.

ACCOMPLISHMENTS:

1. Military specification MIL-PRF-85570C was completed and issued on 11 Jun 97. Type II of this specification is now the No-VOC aircraft exterior cleaner and Type V is the Low-VOC wheel well cleaner developed under SERDP. Qualification testing was completed for two Type II products and two Type V products. Qualification letters for these materials were issued 18 Jun 97.
2. Federal specification TT-R-2918 was completed and issued on 4 Apr 97 to specify non-HAP chemical strippers evaluated under SERDP.
3. Development of non-HAP paint purge solvent blend was completed. New product will be manufactured and then be demonstrated in shop trials at the Jacksonville, Cherry Point, and North Island Naval Aviation Depots.

TRANSITION: Mil.Specs. (MIL-PRF-85570C) and Federal Specs. (TT-R-2918) were revised and currently implemented Department of Defense wide.

PROJECT SUMMARY

PROJECT TITLE & ID: Alternate Electroplating Technology; PP-71

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center Aircraft Division - Patuxent River, MD

PRINCIPAL INVESTIGATOR: Mr. Mark Roberts

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective was to replace hazardous plating processes (chromium, cadmium, cyanide, etc.) currently used on Naval aircraft (A/C) and weapon systems. Chromium and cadmium are heavy metal pollutants and carcinogens. The 1990 Clean Air Act Amendment (CAAA) as well as other Environmental Protection Agency and State Departments of Environmental Resources regulations such as the CAAA Chromium Electroplating National Emission Standard for Hazardous Air Pollutants (NESHAP) restrict the emissions from these processes. In addition, Service directives require significant reductions in these hazardous wastes. Alternative plating processes need to be developed and validated in order to comply with these directives, while maintaining aircraft performance and operational readiness.

BENEFIT: The elimination of chromium and cadmium plating significantly reduces the total amount of hazardous materials emitted from Navy overhaul/repair operations. Elimination of chromium plating also eliminates the need for expensive emission control equipment required by CAAA and Air Quality Management Districts legislation (estimated at up to $1M per Depot facility). Furthermore, these alternatives significantly reduce disposal costs of chromium and cadmium from Navy operations. This effort is in direct support of Navy and Department of Defense (DoD) hazardous waste minimization policies and directives. Without the use of adequate replacements, aircraft operational readiness could be curtailed due to excessive environmental degradation and cost. This is particularly important considering the cost of Navy A/C and weapon systems as well as the severely deleterious environment in which the Navy operates. This technology is being coordinated with commercial airlines, equipment and fastener manufacturers.

ACCOMPLISHMENTS: (1) Tin-zinc, zinc-nickel, and the Aluminum-Manganese processes developed as part of this SERDP effort are being presented to the Joint Group for Acquisition Pollution Prevention (JGAPP) - Cadmium alternatives as viable processes for cadmium replacement for most applications. (2) A tin-zinc electroplating bath has been installed at Naval Depot Cherry Point for prototyping purposes. A 100 gallon plating bath has been built for Aluminum-Manganese molten salt plating at Dover Industrial Chrome in Chicago, IL.

TRANSITION: The technology is being implemented at various naval aviation depot and also transitioned to other DoD and commercial applications through JGAPP.

PROJECT SUMMARY

PROJECT TITLE & ID: Aircraft Depainting Technology; PP-81

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center Aircraft Division - Patuxent River, MD

PRINCIPAL INVESTIGATOR: Mr. Joseph Kozol

FY 1997 COMPLETED PROJECT

OBJECTIVE: The objective was to develop non-hazardous replacements for chemical paint stripping use on Navy aircraft, weapon systems and support equipment. Current chemical paint strippers contain hazardous components (i.e., phenols, methylene chloride, and chromates) and depainting operations at maintenance depots are a major source of hazardous waste generation in the Department of Defense (DoD). Federal and state agencies are restricting the use and disposal of these hazardous materials through the Clean Air and Water Acts, Resource Conservation and Recovery Act, and local Air Quality Management Districts. Service directives also require significant reductions in hazardous waste.

BENEFIT: The elimination of the majority of chemical paint strippers would significantly reduce the total amount of hazardous materials generated by the Navy. Furthermore, requirements for emission control equipment for methylene chloride (estimated at $1M/facility) would be eliminated. This effort is particularly important considering the cost of these aircraft and equipment as well as the severely deleterious environment in which the Navy operates. This technology could also be transitioned to the commercial sector (aerospace, automotive, Marine Corps., etc.).

ACCOMPLISHMENTS: Flashjet™ was extensively tested on aircraft thin, structural aluminum alloys and graphite epoxy composite lay-ups. These studies showed that the process can be used to remove paint systems selectively to the primer or substrate without damage to mechanical properties or adhesive bond strengths.

TRANSITION: On July 28, 1997, the Naval Air Systems Command released a process approval letter and specification for the use of Flashjet™ on all Navy aircraft metallic surfaces. Approval for use on Navy composites is expected prior to 1999. Additionally, Flashjet technology has also successfully transitioned to the Environmental Security Technology Certification Program (ESTCP) for demonstration/validation of Flashjet on rotary-wing aircraft (helicopters) that are common across the Army, Navy, and Air Force.

PROJECT SUMMARY

PROJECT TITLE & ID: Encapsulated Micron Fire Suppression Technology; PP-113

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Dr. Charles J. Kibert

FY 1997 COMPLETED PROJECT

OBJECTIVE: This project developed and tested a new fire suppression concept leveraged on former Soviet aerosol technology for use in a wide variety of critical fire protection roles. Halons, while powerful fire suppressants, cause ozone depletion and are being eliminated. Halon 1301 replacement candidates identified thus far are 2-3 times less effective than Halon 1301 in fire suppression efficiency. Known replacement agents require major modifications to piping, nozzles, and other components of the delivery systems. Suitable replacements resulting from existing programs and technologies are not available or projected to be available in the near term. A class of environmentally safe agents that can fulfill some of these fire suppression roles is needed to maintain operational readiness. An aerosol suppressant, known as Encapsulated Micron Aerosol Agent (EMAA), may provide the Department of Defense (DoD) with an environmentally and occupationally safe agent that has six times the fire suppression capability of Halon 1301 by weight. It requires no piping or pressure cylinders and will be a fraction of the cost of Halon 1301 in installation and life cycle costs. It also allows delivery strategies other than total flood and can be placed locally in high fire risk locations within a facility.

BENEFIT: If successful, pyrotechnically generated aerosols will provide DoD with an option to replace Halon 1301 with non-ozone-depleting fire suppressants. EMAA will also provide superior performance on a weight and volume basis. The result will be new applications such as fire protection systems that can be easily built into deployable shelters, hand thrown and remotely launched devices that can be used to provide "first-aid" to begin the process of extinguishment, and the potential to protect large fuel storage tanks from destruction via compact fire suppression systems. DoD will receive royalties for products created and sold as a result of the research and development.

ACCOMPLISHMENTS: Demonstrated that a fire can be extinguished by a carrierless aerosol (silicon dioxide particles of 7 nm in average diameter). The extinguishment efficiency of a silicon dioxide aerosol using air, CO_2, or N_2 as driving gases converges to 4.5, 3.8, and 3 mgrms/cm2. The driving gas has no influence in the extinguishing mechanism of the silicon dioxide.

TRANSITION: Agent specifications and application data will be provided to Air Force Civil Engineer Support Agency and industry.

PROJECT SUMMARY

PROJECT TITLE & ID: Solid State Metal Cleaning; PP-116

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Wright-Patterson Air Force Base, OH

PRINCIPAL INVESTIGATOR: Mr. Phil D. Mykytiuk

FY 1997 COMPLETED PROJECT

OBJECTIVE: There are two technical objectives to be achieved by this project: (1) to develop and transition to a Department of Defense (DoD) customer a cleaning process for large (and small) aircraft components that do not require the use of water or volatile organic compounds (VOCs); and (2) to develop a process that will allow components to proceed directly to the next step in the process for surface cleaning without the need for subsequent treatments involving water or organic solvents.

BENEFIT: The project benefits are improved worker safety, reduced environmental liability, reduced cost of storage, tracking, handling and disposal of hazardous waste, and uninterrupted production and repair of metal aircraft components.

ACCOMPLISHMENTS:

1. Completed technical analysis and testing of system to clean Navy firefighting and National Aeronautics and Space Administration (NASA) faceshield equipment (prior to bonding thermal coatings). Specific applications have been targeted, including a hypergolic tank from the Delta launch vehicle, a section of isogrid material from the Space Station, and NASA astronaut helmet visors.
2. Initiated final modification for production processes including installation of the ozone exhaust system and the safety interlock.

TRANSITION: This technology is being transitioned to Navy Depots, NASA, and Air Force Air Logistics Centers.

PROJECT SUMMARY

PROJECT TITLE & ID: Large Area Powder Coating; PP-121

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Wright-Patterson Air Force Base, OH

PRINCIPAL INVESTIGATOR: Mr. Michael Halliwell

FY 1997 COMPLETED PROJECT

OBJECTIVE: This project was to provide powder materials and technology to improve aircraft coating performance and increase environmental acceptability. These powder materials will enable the minimization or elimination of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) used in manufacturing and coatings applications. Furthermore, the coatings will exhibit improved performance including improved durability, cleanability, impact resistance, solvent resistance, mar resistance, corrosion resistance, and enhanced appearance. Material research and development includes one or more of the following: (1) Crosslinkable Resin Powders; (2) Pigmented Polymer Beads; (3) Microballoon based pigments; and (4) Hollow fibrillar pigments. The powder materials will be formulated in low and zero VOC coatings.

BENEFIT: The research and development will lead to low or zero VOC coatings that will be easier to clean, have a more uniform appearance, and be less susceptible to weathering effects. As a result, repainting and touch up requirements will be reduced, thereby producing significant life-cycle cost savings. The effort is also applicable to the commercial aircraft and automotive industries.

ACCOMPLISHMENTS: High velocity thermal spray (HVTS) technology has been used to apply new zero VOC formulations. Also tested is a urethane polymer bead formulation that cuts VOC emissions by over 50 percent. The "Nylon-12" formulation has shown uniquely superior corrosion protection on wire brushed, uncleaned, unprimed, Naval Research Laboratory (NRL) standard prerusted panels of highly corrosion-prone 1010 hot roll steel. There was no undercutting after 1000 hours of cyclic salt spray, which is a breakthrough in coatings capability. Sprayable Kynar has been formulated in a camouflage green color and tested against mil-spec requirements.

TRANSITION: This is an applied research effort that will transition to Warner-Robins Air Logistic Center through the CTIO (Coatings Technology Integration Office) at Wright-Patterson Air Force Base.

PROJECT SUMMARY

PROJECT TITLE & ID: Laser Cleaning and Coatings Removal; PP-139

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Wright-Patterson Air Force Base, OH

PRINCIPAL INVESTIGATOR: Mr. Stephen Fairchild

FY 1998 FUNDS: $950K

OBJECTIVE: The objective of this effort is to provide a field demonstration of a prototype laser-based facility to demonstrate environmentally acceptable and cost competitive cleaning and coatings removal from weapon system components. This project will design a self-contained cleaning and coating removal system, design a waste product collection system, and complete preliminary systems engineering. The design will be approved by engineering, the Environmental Protection Agency, and the Occupational Health and Safety Act.

BENEFIT: This project will demonstrate a laser-based coating removal and cleaning process for a wide range of aircraft components having different sizes and materials. The recommended process is expected to be highly cost effective by eliminating the present and future air, solid, and water polluting methods. Thus, it will reduce or eliminate the costs for hazardous stripping of materials, reduce containment costs for solid, liquid and vapor waste streams, and eliminate the legal liabilities associated with waste disposal.

TECHNICAL APPROACH AND RISKS: This effort will implement the technical approach determined in the FY 1993 preliminary design and expand this to a detailed final design. Additionally, this program will fabricate, evaluate, develop, and demonstrate a state-of-the-art automated, controllable coating removal and cleaning system (a repair or remanufacturing cell or process). Various aircraft media controls, robotics sensors, and instrumentation are currently available commercially and may be applied to the system. Software will have to be developed/modified to control the production system. Systems design must incorporate all applicable safety devices and features. The risks with this assessment are associated with availability and adequacy of Air Force, Navy, Army, and industry data. The system will maneuver the laser beam around complex geometries whether on manual or automatic control modes. All effluent gases and particulates will be treated and/or captured. Once the system is built, it will undergo a rigorous confirmation test scheme.

ACCOMPLISHMENTS: The laser chiller was successfully tested. Los Alamos National Laboratory has assembled the spectral sensor system and testing verified that the system surpasses the speed requirement.

TRANSITION: This project will be transitioned to the National Defense Center for Environmental Excellence for further development and demonstration.

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced Fire Fighting Streaming Agent; PP-158

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall Air Force Base, FL

PRINCIPAL INVESTIGATOR: Dr. Charles Kibert

FY 1998 FUNDS: $450K

OBJECTIVE: This project seeks to identify, evaluate, and validate environmentally and occupationally safe streaming agents that are drop-in replacements for Halon 1211 in wheeled 150 lb. flight line fire extinguishers, in aircraft portable fire extinguishers, and in facility portables. Programs to find a replacement for Halon 1211 were initially directed at chemicals that were available in production quantities. Research indicated that even the most powerful replacements available in these quantities would require 2 to 3 times as much agent as Halon 1211 to extinguish a fire. The best agent from among this group, perfluorohexane, had restrictions placed on it in the Environmental Protection Agency (EPA) Significant New Alternatives Policy (SNAP) listing because of its long atmospheric lifetime. Because of this restriction and an Air Force Civil Engineering/Logistics (CE/LG) re-validation of the requirement for a clean streaming agent, a program to explore several promising families of laboratory scale chemicals was initiated.

BENEFIT: The phase out of ozone depleting chemicals (ODCs) has threatened the ability of the military to provide a powerful, clean means of suppressing fires previously afforded by Halon 1211. The replacements originally developed as substitutes for Halon 1211 have all been caveated for greenhouse warming potential or ozone depletion by the EPA. The Advanced Streaming Agent will be developed from chemical families which have none of these negative global environmental impacts. In addition to the military, the civilian sector, particularly aircraft companies, have had essentially the same problem as the military with regard to the phaseout of Halon 1211. This is a technology that has dual use potential and will serve the needs of multiple sectors of the civilian fire fighting community as well as the three military services and the U.S. Coast Guard.

TECHNICAL APPROACH AND RISKS: Agents from several promising chemical families will be synthesized, then subjected to several key tests to determine their overall suitability: fire suppression effectiveness, limit testing for lethality, storage stability, materials compatibility and global environmental impacts. The agents are expected to emerge from one of four families of chemicals: tropodegradable halocarbon, phosphonitrilics, silicon compounds, or organometallics. As work progresses, additional chemical families will be considered for screening. At each stage of the screening process, failure to meet a given criterion will eliminate a compound from further consideration. Compounds that successfully negotiate the screening will be further tested to determine their lethality and cardiotoxicity levels for use

in obtaining EPA approval. Medium scale fire suppression effectiveness will be determined along with initial delivery system parameters. Quantitative structural activation reaction (QSAR), tissue uptake studies, and pharmokinetic modeling will be initiated. Pilot plant studies to assess large scale synthesis methods will be accomplished. It is expected that 2 to 5 agents may survive the initial screening and testing. The risks for this effort is moderate. It is known that some of the chemicals proposed for testing are 10 to 100 times more powerful as fire suppressants than the Halons with the major unknown being the toxicity of these materials. Consequently, rapid assessment of the toxicity of these substances will be a priority.

ACCOMPLISHMENTS: This Research and Development effort has identified unsaturated brominated compounds, and blends of tropodegradable agents such as octafluoro-butene, and 1-bromopropane as Halon 1211 replacements to fulfill all requirements.

TRANSITION: The Air Force, as Project Reliance lead agency for streaming agent development, has received support for this approach from the Navy and Army. This is an exploratory development project which will transition to 6.3 advanced development. Selected agents will be subjected to large scale testing by teams of seasoned Air Force/Navy/Marine Corps firefighters against a variety of two and three dimensional scenario fires. Firefighter exposure data and combustion product interaction information will be analyzed to insure that the compound(s) selected meet both military and EPA requirements.

PROJECT SUMMARY

PROJECT TITLE & ID: Life Cycle Engineering and Design Program; PP-304

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: Environmental Protection Agency

LAB: National Risk Management Research Laboratory - Cincinnati, OH

PRINCIPAL INVESTIGATOR: Mr. Kenneth R. Stone

FY 1998 FUNDS: $300K

OBJECTIVE: The objective is to take lessons learned from the Department of Defense (DoD) cases and other industrial operations Life Cycle Assessments (LCAs) being funded by the Environmental Protection Agency (EPA) to generate a design guide for implementing life cycle principles on environment, performance and cost as an aid to decision-making. This project applies LCA principles to selected DoD operations in order to identify and test potential technical solutions to reduce reliance on toxic chemicals and solvents in industrial and DoD operations.

BENEFIT: The anticipated benefits include the elimination of an EPA 17 chemical, methyl ethyl ketone (MEK), from the radome depainting process, along with volatile organic compound (VOC) emissions. While chemical agent resistant coating (CARC) undergoes tests and reformulation to reduce VOC content, this project shall generate guidance with applicability to facility CARC painting operations DoD-wide. Techniques and product improvements will generate cost savings and operational efficiency.

TECHNICAL APPROACH AND RISKS: With the completing of the base LCAs and technology evaluations for the alternative chemical depainting and the CARC projects, the next step is to conduct an examination of the impacts of these operations on a more detailed level in order to assess the health, ecological, and resource depletion aspects of the alternatives. Two impact assessments are planned: one on CARC painting operations and the second on alternative chemical depainting. In the CARC project, it has been discovered that a painting procedure in the field can vary significantly, depending upon the installations practices. This impact assessment will provide a good comparative basis to test the application of the methodology to distinct, specific sites, providing key information on the validity of our approach. In the case of the depainting study, significant issues have arisen regarding the impacts from the production of constituents, specifically propylene carbonate, n-methyl-pyrolidone and more recently, benzyl alcohol. The impact assessment will focus on these chemicals as components of a solvent formulation, identifying life cycle impacts and documenting the information as a basis for comparison. Another component of the Life Cycle Engineering and Design (LCED) Program is the integration of cost/benefit tools with the LCA methodology. EPA began this component of the study this year as an EPA funded effort to lay the groundwork for the methodology and submit it for peer review. It will be tested in selected federal operations and will be a component of the final report for the LCED program in 1998. To enhance technology transfer, a lessons learned document will be generated with a full presentation of difficulties

and successes experienced to date.

ACCOMPLISHMENTS: The National Risk Management Research Laboratory (NRMRL) has tested several solvent formulations as possible alternatives for MEK and methylene chloride in aircraft radome and fuselage depainting. Technology demonstrations with the Army showed the potential for significant real reductions in the quantity of CARC paint needed to coat military vehicles, and demonstrated the fact that painting operations in the field can vary significantly among installations. A life cycle inventory (LCI) with the Navy and the Department of Energy (DOE) identified environmental effects of selected energetic materials a step in improving design. To date, three reports have been cleared for publication, funded by EPA, and four other reports are pending publication.

TRANSITION: Ultimately, the product of this work will be a guidance document, or model, for conducting LCAs of DoD and related industrial operations in order to improve design and process efficiencies. This document will demonstrate the experiences of the research team and offer a streamlined approach that reduces the cost of conducting an LCA.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Expert Solvent Substitution Data Base; PP-331

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: Environmental Protection Agency

LAB: Office of Environmental Engineering & Technology Demonstration - Washington, DC

PRINCIPAL INVESTIGATOR: Mr. Myles Morse

FY 1997 COMPLETED PROJECT

OBJECTIVE: The Enviroene (ES) project creates a Federal pollution prevention network and solvent alternatives umbrella by integrating technical information and networks from other federal agencies. ES will assist the Department of Defense (DoD) and supporting industries with easy access to information on available substitutes to meet the ozone depleting substance (ODS) and toxics reductions under the Clean Air Act, and Executive Order 12856. The Expert Solvent Alternatives Data Base referred to as the solvent umbrella, will allow users to access solvent alternative information through a single easy to use command structure which will seamlessly access and retrieve information from as many as 16 component federal state and private data bases. The Solvent Umbrella will utilize state of the art electronic navigation, translation, and search tools in the Internet environment. The search architecture will allow information to be synthesized and weighted specific to user's process needs. The project will add new alternatives to the umbrella based on ongoing work in existing test bed centers. The project will include targeted training for DoD. The umbrella will give users access to solvent alternatives based on their specific process needs, and will reduce redundant requirements testing.

BENEFIT: The benefits of this effort for DoD, the Department of Energy (DOE), and the Environmental Protection Agency (EPA) include better centralized access to pertinent information to reduce the use of toxic and ODS and a reduction of redundant research efforts. The benefits to industry include easier access to technical information allowing them to implement alternatives and reduce the emissions of ODS and other toxics and assist in meeting the bans under the Clean Air Act. Industrial benefits include monetary savings and liability reduction due to implementing pollution prevention alternatives.

ACCOMPLISHMENTS: (1) DoD intuitive access solutions implemented on test site for comment. (2) Experimental pollution prevention cooperative templated on Research and Development site for workgroup comment. (3) Search 97 version of 2.0 and 2.10 evaluated. (4) Updated version of Joint Services P2 Library added with direct links to Naval Facilities Engineering Service Center (NFESC) Web site. (5) DOE/EPIC file format and directory structure evaluated for future indexing on ES Earth 1 transition server: software configured.

TRANSITION: The ES database will be maintained and updated on the EPA earth1 server and will be accessible to public.

PROJECT SUMMARY

PROJECT TITLE & ID: Acid Recycle; PP-422

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: Department of Energy

LAB: Los Alamos National Laboratory - Los Alamos, NM

PRINCIPAL INVESTIGATOR: Dr. Thomas Mills

FY 1997 CANCELLED PROJECT

OBJECTIVE: The objective is to demonstrate removal of nitric and hydrochloric acids from radioactive liquid waste streams to levels meeting or exceeding Federal and state regulations on liquid effluents. This will require at least 99 percent recycle of nitric and hydrochloric acid from waste solutions. Recycle acid will be reconcentrated sufficiently to be used for dissolutions, etc. in lieu of makeup acid. The project will develop, construct, and test process systems. Existing effluent streams from the Los Alamos National Laboratory (LANL) Plutonium Facility to the Waste Treatment Facility contain 1-6 molar concentrations of nitric or hydrochloric acid, along with other dissolved nitrates or chlorides, and also contain small amounts of dissolved actinides. These nitrates and chlorides exiting the Plutonium Facility represent the primary source of these ions for the Waste Treatment Facility to handle. Following treatment, effluent liquids from the Waste Treatment Facility still contain nitrate and chloride concentrations in excess of the National Pollutant Discharge Elimination System (NPDES) limits of 45 ppm nitrate and 250 ppm chloride.

BENEFIT: This research and development will enable continued operation of the LANL Plutonium Facility by meeting or exceeding increasingly stringent environmental regulation on liquid effluents. Costs of treating present waste acid streams will be greatly reduced. Direct cost savings are difficult to estimate, but the annual cost of all work in connection with the Plutonium Facility is in excess of $70M. If environmental objectives cannot be met, the Facility will not be permitted to operate. Amounts of transuranic radioactive waste (TRU) for eventual disposal will be reduced (yielding cost savings), and the waste forms will have greater chemical stability. Production of clean effluent waste streams may allow elimination construction of a pretreatment room at the proposed new Radioactive Liquid Waste Treatment Facility at LANL.

ACCOMPLISHMENTS: Project terminated in April 1997 following the Annual SERDP In-Progress Review (IPR) due to lack of a viable transition path for the technology within the Department of Defense.

TRANSITION: The project is being transferred to the Department of Energy's Los Alamos National Laboratory for further development.

PROJECT SUMMARY

PROJECT TITLE & ID: High-Performance, Lead-Free Electrical Sealants; PP-429

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Energy

LAB: Sandia National Laboratory - Albuquerque, NM

PRINCIPAL INVESTIGATOR: Dr. John A. Emerson

FY 1997 COMPLETED PROJECT

OBJECTIVE: A lead-free material that replaces the high-performance, electrical-grade, fuel-resistant polysulfide sealant currently used for electrical components in aircraft (MIL-S-8516F) needs to be identified, characterized, and developed. The polysulfide sealant MIL-S-8516F, now in use, contains lead oxide. A lead-free "drop-in" replacement for MIL-S-8516F will help the military depots and air logistics centers achieve their objective of reducing the use of lead, a hazardous material that will be subjected to strict Environmental Protection Agency (EPA) regulations. Work was performed to see if toluene sealant solvents, also targeted by the EPA, can be replaced with nonhazardous solvents. Through this work, new material qualification procedures for the nonhazardous sealant will be developed, material parameters for viscosity control will be introduced, and a method of material fingerprinting (which will permit tracking of lots from the supplier to government applications) will be developed.

BENEFIT: This project will cooperate with the appropriate government agencies and vendors to develop an environmentally responsible, drop-in material that will provide solutions to two major concerns: limited availability and cradle-to-grave product responsibility. Because of stricter requirements resulting from hazardous waste minimization, lead-containing (8516 type) polysulfides will become difficult or nearly impossible to acquire in the next few years. Also, vendors are finding it difficult to obtain the proper grade of the lead peroxide curative required for 8516 type sealants. Suppliers may have to assume cradle-to-grave responsibilities for materials such as the MIL-S-8516F sealant. If no lead-free substitute is found, these cradle-to-grave responsibilities could increase sealant costs considerably, and mission readiness of aircraft and weapons systems would be lessened.

ACCOMPLISHMENTS: A rewrite of MIL-S-8516F as the MIL-PRF-8516G, "Sealing Compound Polysulfide Rubber. Electrical Connectors and Electrical Systems, Chemically Cured" has been completed. Two Society of Automotive Engineers (SAE) Aerospace Materials Specifications (AMS) are being written. To establish better baseline data for new materials under development, Lockheed Martin in Marietta and Fort Worth are providing input to issues important to C-130 and F-16 aircraft.

TRANSITION: MIL-S-8516F and MIL-PRF-8516G are being revised to include lead/free environmentally benign electrical sealants for DoD applications and DOE weapons program applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Laser Ignition to Replace Chemical Ordnance Igniters for Propulsion; PP- 680

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Army

LAB: Army Research Laboratory - Aberdeen Proving Ground, MD

PRINCIPAL INVESTIGATOR: Dr. Brad Forch

FY 1998 FUNDS: $263K

OBJECTIVE: The laser is a non-polluting ignition source that can replace thousands of pounds of hazardous materials in the life cycle of a single armament system. The objective is to eliminate hazardous components in ordnance (including ordnance manufacturing); to reduce the production of waste and unnecessary energetic materials in manufacturing for propulsion systems which includes large, medium and small caliber guns, rockets and missiles; to eliminate inventories of lead containing primers (lead styphnate and lead azide); and to eliminate hazards in storage and disposal of these components. The long-term goal is to develop a Universal Laser Ignition System (LIS) for propulsion that is free from lead and other hazardous and polluting chemicals.

BENEFIT: The laser is a non-polluting instrument. Hazardous components (lead containing igniters) in ordnance and ordnance manufacturing are eliminated. A universal igniter for propulsion systems is envisioned. The laser igniter replaces technology that is over 100 years old. The technology provides a safer system for soldiers in the field and numerous performance benefits which include higher firing rates, reduced hazard from accidental ignition from electromagnetic radiation, full computer control of the laser and thus the ignition event, and another completed link in the digital battlefield.

TECHNICAL APPROACH AND RISKS: The technical approach involved in this work is to perform fundamental research on the interaction of energetic materials with intense laser radiation to achieve reliable and reproducible ignition. Fundamental research is then transitioned (in house) to design and fabricate a small scale prototype laser-based ignition system. This prototype ignition system is then transitioned from small scale to a large scale prototype igniter. The large scale igniter is then tested on an armament/propulsion system and demonstrated. The overall process is recycled (back in the laboratory and through the demonstration process) to make performance improvements. Finally the ignition system is demonstrated to the user and Program or Product Manager(PM). No major technical risks are foreseen in the approach at present.

ACCOMPLISHMENTS: The researchers prepared a patent disclosure on large caliber sapphire window and assembly, and on an inexpensive disposable glass bead wind for 30 mm ammunition. The ignition system has been identified as having a great potential for small arms. Using the LIS as the ignition source, the Crusader howitzer could fire at 15 rounds/minute. The system was also demonstrated on the 30 mm

cannon. In each case the action times were less than 4 ms, as required by the PM. This was a major accomplishment in the acceptance of the LIS. More than 14 Small Business Innovative Research (SBIR) agreements and five Cooperative Research and Development Agreements (CRADAs) have been established.

TRANSITION: The Program Manager for Crusader has already embraced this technology. The results are directly transferrable to other Army, Navy and Air Force systems including PM-Paladin, PM-Apache, PM-Bradley, and Light Forces. A CRADA with Remington Arms has been submitted to transition this technology for use in small arms.

PROJECT SUMMARY

PROJECT TITLE & ID: Recycling Propellants in Nonpolluting Supercritical Fluids: Novel Computational Chemistry Models For Predicting Effective Solvents; PP- 695

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Army Research Laboratory - Aberdeen Proving Ground, MD

PRINCIPAL INVESTIGATOR: Dr. Betsy Rice

FY 1998 FUNDS: $400K

OBJECTIVE: Waste solid explosives and gun propellants are destroyed primarily by open pit burning or incineration. Extraction and recycling of the propellant using a non-polluting, inert supercritical fluid (SCF) solvent such as CO_2 has economic and environmental advantages. Although the ingredients in composite (nitramine based) propellants are insoluble in CO_2, solubility is enhanced when trace amounts of simple polar modifiers are added to the SCF solvent. The objective of this project is to determine the optimal physical conditions and chemical makeup of an effective SCF CO_2 solvent with added polar modifier using well-established computational chemistry techniques. The technology developed in this project will have application to nitramine-based explosive and propellant formulations.

BENEFIT: The principle benefits include prevention of pollution associated with disposal of Army and Navy explosives and gun propellants and associated reduction of life cycle cost of munitions. Recycling is an alternative to current open burning/incineration of gun propellants which is increasingly restricted.

TECHNICAL APPROACH AND RISKS: Two complementary theoretical investigations on properties and effectiveness of polar modified-CO_2 SCF solvents will be pursued in parallel. The first investigation will focus on the actual dynamic event for dissolution of an RDX crystal in an SCF solvent. Solvation dependence on the physical conditions of the system (far from or close to the critical point of the SCF) will be examined. The second investigation focuses on determining modifier properties that enhance solubility of RDX in the SCF solvent, using rigorous quantum mechanical methods.

ACCOMPLISHMENTS: (1) CO_2-CH_3CN Symmetry Adapted Perturbation Theory (SAPT) dimer interactions have been completed. (2) Quantum mechanical calculations have been performed for an extended number of points on the CH_3CN dimer, DMNA-CO_2 and DMNA-CH_3CN potential energy surfaces using the approximate SAPT method. (3) Transferability of the RDX crystalline potential has been tested for another nitramine explosive, HNIW, and has predicted to within a few percent the measured crystallographic structures of three polymorphs. This suggests that the potential energy function developed for RDX is suitable as a crystalline nitramine descriptor.

TRANSITION: Results of this effort are being transferred to Army and Navy recycling initiatives.

PROJECT SUMMARY

PROJECT TITLE & ID: Fluorinated Ship-Hull Coatings for Non-Polluting Fouling Control; PP-756

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Command Control and Ocean Surveillance Center - San Diego, CA

PRINCIPAL INVESTIGATOR: Dr. Kenneth Wynne

FY 1997 COMPLETED PROJECT

OBJECTIVE: The overall goal of this project was to develop non-polluting, easy fouling release, hull coatings based on flexible, low surface-energy polymers. Ship hull protection from marine fouling organisms is essential for efficient fleet operation and energy conservation. Presently, the Navy standard antifouling coating contains copper as a toxicant. The copper leaching from these coatings represents an environmental hazard and is the subject of increasing regulation which will impact normal fleet operations.

BENEFIT: A non-polluting, easily cleaned coating will be synthesized which will contain no leachable toxics and will have a non-wetting, low-energy surface which resists attachment of marine fouling organisms and permits easy removal of fouling which does adhere. These coatings will benefit all operating vessels and structures and will have obvious commercial application.

ACCOMPLISHMENTS:

1. The new fluorinated oxetane (7-Fox) sol-gel coatings have been applied to test panels, immersed at two test sites, and evaluated for fouling release behavior. These elastomeric coatings based on 7-Fox have been found to be the first fluorinated elastomers to show fouling release.
2. Incorporation of fluorinated alkoxy silane crosslinker/siliceous domain precursor has been shown to be effective in generating poly(dimethylsiloxane) based networks with surface properties like fluoropolymers. Atomic force microscopy and optical microscopy revealed that certain compositions display a patterned surface with fluorinated "islands" amidst a poly(dimethylsiloxane) "sea."

TRANSITION: Naval Sea Systems Command will further test this approach.

PROJECT SUMMARY

PROJECT TITLE & ID: Solventless Pyrotechnic Manufacturing; PP-757

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Navy

LAB: Naval Surface Warfare Center - Crane, IN

PRINCIPAL INVESTIGATOR: Dr. Norris Caldwell

FY 1998 FUNDS: $140K

OBJECTIVE: The objective of the project is to demonstrate the application of cast/cure methodology to eliminate the (solvent) hazardous waste and associated volatile organic compound (VOC) emissions in some important areas of military pyrotechnics manufacture. The cast/cure approach to manufacture offers the potential for the virtual elimination of the use of volatile solvents (VOCs) in pyrotechnics processing, while still producing the material in a manner that mitigates hazards (ignition) sensitivity.

BENEFIT: Due to the elimination of hazardous solvent waste and the potential for VOC emissions, expensive solvent recovery and recycling systems would not be needed, and the costs of waste stream treatment would be eliminated. The potential payoff is exemplified by some (projected) procurement figures for FY95: the Department of Defense (DoD) is planning to procure quantities of decoy flares corresponding to a total of about 650,000 pounds of pyrotechnic material, generating from 195,000 to 975,000 gallons of hazardous waste solvent. Based on representative current costs of disposing of waste solvent, annual cost savings from solvent waste elimination alone could be from $2.1M to $10.6M.

TECHNICAL APPROACH AND RISKS: The project will use modern liquid/curable polymeric binder materials to formulate pyrotechnic compositions. Tasks that are significant hurdles for the successful completion of this project include the installation of mixing equipment and development of operational procedures. These tasks are on-going. Other major tasks include laboratory scale formulating, functional testing, scale-up, and performance testing. In a sense, the cast/cure methodology is mature technology since it has been used for some time to process solid rocket motor propellant materials. Therefore, the main risk involved in this effort is not whether cast/cure processing is a viable technology, but whether products formulated for this type of processing, and so produced, will meet established and developing requirements for in-service pyrotechnic products. This effort emphasizes the very important air-countermeasures applications of pyrotechnics.

ACCOMPLISHMENTS:

3. Lab screening of compositions based on commercial energetic and non-energetic binders for "grey-body" pyrotechnic material was completed.
4. Preparations and planning for a major sub-scale test were carried out. This test will make measurements of infrared emission characteristics of experimental cast/cure materials. This testing will

ultimately "pave the way" for the final selection of potential magnesium-teflon-viton "substitute."

TRANSITION: The results of this effort are planned to transition in to both a Navy 6.3 Air Expendables program and to Naval Air Systems Command, PMA-272.

PROJECT SUMMARY

PROJECT TITLE & ID: Solventless Manufacture of Artillery Propellant Using Thermoplastic Elastomer Binder; PP-867

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Air Warfare Center - China Lake, CA

PRINCIPAL INVESTIGATOR: Dr. Thomas Stephens

FY 1998 FUNDS: $300K

OBJECTIVE: The objective is to demonstrate the feasibility of reducing or eliminating the emission of volatile organic compounds (VOCs) and solvents associated with the production of gun propellants by using thermoplastic elastomer (TPE) propellants. New propellant formulations that reduce or eliminate the use of solvents will be developed and evaluated for replacement of current propellants that require solvents to manufacture. Multi-base gun propellant for artillery ammunition creates 0.3 lb of solvent emissions per lb of propellant, and at expected production rates of 3 million lb/yr, this represents the largest source of VOC emissions due to gun propellant production. This project will demonstrate at a pilot plant scale the production of TPE gun propellant by using solventless continuous processing.

BENEFIT: Risk associated with this new technology will be reduced to a level acceptable to program managers without further demonstrations. Once the technology is fully developed and implemented, solvent emissions due to triple-base gun propellant manufacture can be eliminated, including approximately 500,000 lb/yr VOC emissions, 400,000 lb/yr other solvent emissions (contaminated with explosives), elimination of scrap propellant (by reworking propellant in the manufacturing process), cost saving in VOC elimination facility modifications, and elimination of the costs of solvents and of energy costs in heating drying houses.

TECHNICAL APPROACH AND RISKS: New TPE propellant formulations will be designed to permit solventless processing while simultaneously meeting performance and safety requirements. This will require evaluating the most promising TPEs, determining the proper composition and molecular weight of the TPE, and optimizing the choice and amount of oxidizer in the propellant. A solventless manufacturing process will be developed for this propellant by modifying and adapting existing continuous twin screw extrusion technology. Manufacture of the new TPE propellant by the solventless process will be demonstrated at a pilot plant scale. The manufacturability, safety, sensitivity and performance properties of the propellant produced will be evaluated in "proof-of-principle" tests. The main technical risk is that meeting several propellant material property requirements simultaneously may be difficult. In particular, howitzer ammunition requires specific performance characteristics over a wide range of firing temperatures, pressures, and charge loadings; and TPE-based propellants have not been evaluated for a wide range of conditions.

TPEs will be characterized for viscosity and other physical properties for optimizing binder composition. Small scale (1 to 5 kg) propellant mixes will be prepared and evaluated for solventless processability in initial processing studies that will include capillary viscometry and batch extrusion runs. Viscosity data will be used in numerical simulations of the flow of propellant through the extrusion die. These die modeling calculations will be used to optimize the die design to ensure stable flow and accurate dimensions of the extruded propellant. Initial feeder studies will begin to evaluate methods for handling raw materials and feeding them to the continuous processor. These initial processing studies are required before processing the propellant in the twin screw continuous processor in FY 1998.

ACCOMPLISHMENTS: Preliminary feeder tests of nitroguanidine (NQ) and high-bulk-density nitroguanidine (HBNQ), were conducted at Naval Surface Warfare Center (NSWC)-Indian Head. These studies are required to ensure a consistent product composition in the continuous manufacturing process. The roughly spherical HBNQ was relatively easy to feed. The needle-shaped NQ, however, was more difficult to feed at a well-controlled rate using existing equipment. This is mostly due to its low bulk density and cohesion. Equipment modifications should make it possible to feed the NQ with sufficient accuracy.

TRANSITION: For leveraging cost of testing and evaluation, this project will be closely coordinated with efforts to develop a propellant charge for the Crusader 155-mm howitzer, and data on new propellants developed under this project will be provided to the Program Executive Officer (PEO) for Field Artillery Systems in order for the PEO to choose a new solventless propellant formulation to fully develop and qualify for field use. Solventless propellant processing technology developed under this project will be transferable to other gun propellant programs.

PROJECT SUMMARY

PROJECT TITLE & ID: Trapped Vortex Combustor for Gas Turbine Engines; PP-1042

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Wright-Patterson Air Force Base, OH

PRINCIPAL INVESTIGATOR: Dr. W. M. Roquemore

FY 1998 FUNDS: $500K

OBJECTIVE: The goals of this project are to demonstrate the feasibility of developing a Trapped Vortex (TV) combustor that will: (1) reduce aircraft pollutant emissions [nitrogen oxides (NOx), volatile organic compounds (VOCs), CO, and particulate matter (PM)-10] by 60 percent, bringing them significantly below the proposed 1996 Environmental Protection Agency (EPA) regulations, and (2) reduce NOx emissions by 60 percent, bringing them below the 1995 EPA regulation for land and marine based gas turbine engines burning distillate fuels. Since the total amount of emissions from gas turbine engines is directly proportional to the amount of fuel consumed, a 3 percent savings in fuel will also result in a 3 percent reduction in emissions. Since aircraft spend most of their time at high altitudes, a 3 percent reduction in total emissions would reduce global environmental changes due to NOx reduction of ozone in the stratosphere and the greenhouse effect of CO_2 and H_2O emitted from high flying aircraft.

BENEFIT: This project will provide the basis to demonstrate the capability of TV combustors to reduce pollutant emissions and conserve fuel. The environmental objective is to reduce NOx, VOCs, CO, and PM-10 aircraft emissions to 60 percent below the proposed 1996 EPA aircraft emissions regulations and to reduce NOx emissions by 60 percent below the California Resource Board recommendation of 42 ppm for L&M based gas turbine engines burning distillate fuels. The environmental impact of only military aircraft using the TV technology that meets the project goals would be enormous. For example, assume that all existing military aircraft had a TV combustor. The VOCs for the Air Force and Naval bases would drop by a factor of 10 in some cases and the NOx emissions would be reduced by 20 percent to 40 percent depending on the aircraft at the bases. This would permit flight operations and training to continue at current levels with reduced or even eliminated fines due to pollutant emissions from aircraft. If commercial aircraft also had TV combustors, then the environmental and cost impact improves by a factor of 8, since in the U.S. commercial aircraft uses about 88 percent of the jet fuel consumed annually.

TECHNICAL APPROACH AND RISKS: The project will develop an optimized trapped vortex design for use in the General Electric Integrated High Performance Turbine Engine Technology (IHPTET) Phase III prototype gas turbine engine and will evaluate the use of a trapped vortex combustor for reducing NOx emissions in stationary gas turbine engines used on-board Naval vessels for power generation. Three parts are required to make this new combustor system: a new integrated fuel injector/diffuser, TV combustor section, and thermal management system. General Electric (GE) in conjunction with the IHPTET program

will design and test the integrated diffuser and thermal management system. GE and Air Force Research Laboratory (AFRL) will work together on this SERDP project to design and incorporate the low emissions TV combustor portion and will incorporate all three efforts into a final design. The technical approach uses a combined Computational Fluid Dynamics (CFD) design study with an experimental sector rig study to investigate different TV configuration at realistic conditions and with realistic size combustors. TV combustors with three different missions will be investigated. The first mission corresponds to a future high performance aircraft that would utilize IHPTET engine technology. The second mission corresponds to that of a conventional aircraft. This mission is included to provide the Air Force with the option of upgrading existing engines to a low emissions, fuel efficient TV combustor in the future. The third mission corresponds to possible future forward-fit for new purchases of LM2500 engines used aboard Naval vessels.

ACCOMPLISHMENTS:

1. AFRL researchers evaluated a tri-passage Integrated Diffuser, Injector, Flameholder (IDIF) with 3 cavity configurations. Additionally, a parametric study of 18 different cavity designs was completed using a bi-passage IDIF. The result of this study was a ranking of the cavity designs based on NOx, CO, unburned hydrocarbons (UHC), lean blow-out limits, temperature exit profile, and combustion efficiency.
2. GE performed a model evaluation study of bi- and tri-passage IDIFs for the main combustor with different cavity or pilot combustor designs. Some specific differences were noted in the two designs. Some differences between the model study and the experimental results have been noted.

TRANSITION: The combustor will be inserted into the full-scale prototype IHPTET test.

PROJECT SUMMARY

PROJECT TITLE & ID: Pesticide Reduction through Precision Targeting; PP-1053

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Department of Agriculture

LAB: Imported Fire Ant & Household Insects Research Unit - Gainesville, FL

PRINCIPAL INVESTIGATOR: Dr. Richard Brenner

FY 1998 FUNDS: $310K

OBJECTIVE: The Department of Defense (DoD) presently uses approximately 1 million lbs of pesticide active ingredient annually, excluding pesticides used during major deployments. In each of these settings, these pests and disease vectors also affect the health of DoD personnel by transmitting pathogens, contaminating foods and surfaces with biologics, and producing allergens. The overall research goal is to reduce pesticide use and risks through the use of precision targeting and comparative risk reduction. This will result in the development of a comprehensive, standardized, verifiable, and documentable system for protecting troops, DoD supplies, and DoD facilities from disease vectors and pests in a manner that reduces pesticide use and risk. This novel precision targeting approach to integrated pest management (IPM) will reduce pollution from pesticides while ensuring control of disease vectors and pests that impact military readiness in three major settings: (1) in military deployments and training exercises, vector-borne diseases, such as malaria, leishmaniasis, dengue, and tick borne illnesses transmitted by mosquitoes, flies, and ticks, cause direct loss in troop combat effectiveness; (2) in the DoD supply system and in DoD supply depots, stored products pests and other pests cause losses to war stocks of military rations and other material such as uniforms and blankets with losses increasing during longer storage times; and (3) on military installations, a wide range of pest species cause damage to buildings, structures, and vegetation.

BENEFIT: Successful execution of this research will, for the first time, provide standardized procedures for achieving comparative risk reductions associated with the broad scope of disease vectors, pests, pesticides, and pesticide resistant populations in military theaters of operation as well as on military installations. Specific payoffs include reduced use of pesticides by as much as 40-80 percent depending on pest problem via a comprehensive, standardized, verifiable, and documentable system and reduced direct and indirect costs of pesticides.

TECHNICAL APPROACH AND RISKS: This research is designed to meet these unique DoD needs by providing sophisticated surveillance of disease vectors and pests combined with a novel process of "precision targeting" selected interventions. Precision targeting is a functional strategy allowing incorporation of independent IPM tools. However, additional research is needed to develop the precision targeting concept further into a standardized, quantifiable risk assessment computer program for determining the necessity of interventions and selection of those that will optimize reduced use of pesticides, risk reductions, and cost effectiveness (comparative risk reduction).

Project research will focus largely on developing a comparative risk assessment model based on spatial probabilities that incorporate techniques of monitoring and detecting pests and risks, and on proving the concept and process for versatile field-use by relatively untrained personnel. Few technical difficulties should be encountered because the project's research team has diverse expertise that is capable of executing this complex mix of basic and applied research, in part due to existing United States Department of Agriculture (USDA) funding. This project leverages existing scientific expertise within USDA Center for Medical, Agricultural, and Veterinary Entomology (7-9 scientists) with technical support and equipment made possible through the SERDP funding to address this important unique DoD issue of preventing pollution while safeguarding supplies, facilities, and personnel from disease vectors and pests.

ACCOMPLISHMENTS:

1. Detection of pesticide resistance in German cockroaches: Analysis of detoxification enzyme expression among 15 field-collected strains of German cockroach has been completed. These results poignantly indicate that multiple resistance is a common mode of resistance among this species.
2. Finalization of methods and algorithms to conduct comparative risk reductions: The development of methods to conduct a comparative risk reduction when interventions are warranted was another significant accomplishment.
3. Finalized protocols: Protocols for the integration of typical toxicology and exposure data on biocides (from the Environmental Protection Agency) with spatial patterns of land use and human activity were completed. It was concluded that only in very well controlled experimental situations for specific organisms was it possible to conduct a full toxicological analysis and that it would be impossible to attempt to include this type of rigorous analysis for every possible toxicant within the DoD system.
4. Sustained routine monitoring of pests to reduce pesticide use: Techniques developed for monitoring and mitigating pest ants at the Bachelor Officers Quarters (BOQ), Jacksonville Naval Air Station, were continued to demonstrate proof of concept for long term monitoring to reduce need for pesticides and this process is duplicated at the Naval Hospital, with some exceptions.

TRANSITION: Following successful development and testing of this concept, full documentation will be presented to the Armed Forces Pest Management Board for possible expansion to other pests and DoD operations, thereby resulting in the greatest possible reduction in pesticide use.

PROJECT SUMMARY

PROJECT TITLE & ID: Low VOC Chemical Agent Resistant Coatings (CARC); PP-1056

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Army Armament Research, Development, and Engineering Center - Picatinny Arsenal, NJ

PRINCIPAL INVESTIGATOR: Mr. Robert Katz

FY 1998 FUNDS: $900K

OBJECTIVE: This project will develop a low volatile organic compound (VOC) Chemical Agent Resistant Coating (CARC) system suitable for use on military equipment in which the materials and processes for the reformulation/application, stripping, and disposal are optimized and in compliance with current and anticipated regulatory requirements. The primary focus is to reduce the VOC of the polyurethane topcoat from 3.5 lb/gal to 1.8 lb/gal. A secondary objective will be to eliminate the hazardous air pollutants (HAPs) and toxic solvents used in the current topcoat formulation.

BENEFIT: At current annual usage nationwide, estimated to be 3 million gallons per year, a CARC targeted to a 1.8 lb/gal VOC limit would save at least 5 million pounds of VOC per year in the application of the coating, proportionately reduce photochemical smog generation and avert Notices of Violation (NOVs) at user facilities including depots, air logistic centers (ALCs), bases, and original equipment manufacturers. Those VOCs which would be reduced or eliminated include: methyl isobutyl ketone, methyl isoamyl ketone, toluene, xylene, and butyl acetate, all of which are HAPs.

Furthermore, the technology developed by this project will eliminate the need to install emission control devices for approximately twelve facilities for a total cost avoidance of $60 million for equipment installation and $3 million saved in annual operating costs. By developing one CARC topcoat for use by all the services substantial savings will result in procurement and logistics operations.

TECHNICAL APPROACH AND RISKS: The technical approach for the reformulation work will focus on high performance, water reducible (WR) polyurethane binder systems which have the potential for chemical agent resistance and meets the performance requirements of the Army, Air Force, and Marine Corps. Candidate polymers will be obtained from raw material suppliers, screened for live agent resistance, and formulated into camouflage topcoats. Requirements for the WR CARC will include compatibility with current camouflage pattern painting procedures and universal use under all current and foreseen VOC regulations.

The approach to the stripping work will be to focus on evaluation of currently used methods of removal to optimize the processes for de-painting and disposal of the CARC developed under this project. A review will be made of current technology including those projects conducted by: the National Defense Center for

Environmental Excellence (NDCEE), the Joint Depot Environmental Panel (JDEP), the three services under the SERDP; as well as a review of existing CARC stripping operations at depots, original equipment suppliers and other manufacturing/maintenance facilities. Selected technologies will then be tested to determine the applicability to strip the new CARC as applied to a variety of substrates (aluminum, steel, composites). Processes will be adjusted to permit the optimum utilization of technologies to minimize environmental impacts of the stripping and disposal operations consistent with economical operations at the manufacturing and maintenance facilities. Emphasis will be given to non-chemical means of stripping due to the large quantities of hazardous wastes which are generated by the use of chemicals.

ACCOMPLISHMENTS:
1. Army Research Laboratory (ARL) researchers established a low VOC formulation for the basic Army green camouflage color that meets the VOC requirement of 1.8 #/gal (max) as sprayed and is HAP free. The formulation meets or exceeds all performance requirements of the currently fielded CARC topcoat. Significant improvements in flexibility, particularly at low temperature have been achieved as well as marked improvements in mar resistance.
2. ARL has filed two patent disclosures based on the technology of WR CARC finishes, using both siliceous and non-siliceous extender pigmentation.

TRANSITION: ARL has sent and received in return non-disclosure agreements for this technology from two paint companies. Army, Navy, and Air Force will work with industry to develop specifications.

PROJECT SUMMARY

PROJECT TITLE & ID: Eliminate Toxic and VOC Constituents from Small Caliber Ammunition; PP-1057

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Army Armament Research, Development, and Engineering Center - Picatinny Arsenal, NJ

PRINCIPAL INVESTIGATOR: Mr. Wade Bunting

FY 1998 FUNDS: $900K

OBJECTIVE: The objective of this program is to develop non-toxic small caliber ammunition which will meet U.S. and North Atlantic Treaty Organization (NATO) performance standards for all calibers (5.56 mm, 7.62 mm, 9 mm, .50 caliber). This effort will focus on eliminating toxic components in the projectile core, primer, and manufacturing processes. All proposed solutions must be economical and feasible while meeting all environmental regulatory guidelines and standards over the life cycle of the cartridge.

BENEFIT: This project will develop a non-toxic cartridge that will eliminate the environmental and hazardous effects that are associated with current ammunition. It is anticipated that approximately $2.5 million required for waste removal at each outdoor firing range as well as the $100K annual cost for lead contamination monitoring will be eliminated. Furthermore, the 601 indoor National Guard ranges currently closed will no longer require $150K/each in upgrades to become operational, thereby saving $90 million. Lake City Army Ammunition Plant (LCAAP) yearly costs will be reduced by $100K per year from elimination of lead sludge treatment.

TECHNICAL APPROACH AND RISKS: Projectile core: The approach is to conduct the appropriate environmental studies of candidate projectile core materials to ensure their viability for use in non-toxic projectiles, and provide methods by which the recovery of the material is optimized and release is minimized. Environmental testing will include leaching, corrosion, and biological uptake studies to determine the form chemistry, mobility, and uptake of unrecoverable materials. These results will provide guidance for optimizing the environmental stability and thus maximizing recovery and recyclability of the next generation of projectile materials. The major areas of concern for projectile core replacement are the terminal ballistic performance (lethality/penetration) and mobility/toxicity of materials. In addition, the final candidate must also conform to all bio-uptake requirements.

Cartridge primer: This effort will utilize a new class of non-toxic energetic materials called Metastable Interstitial Composites (MICs) as a replacement for current primer materials which include lead styphnate, barium nitrate, and antimony sulfide. A MIC material is an engineered energetic consisting of two or more chemical species that are exothermically reactive with each other. There are three areas of concern for replacement of current primer materials. First, the MIC compounds have never been used in small arms

percussion primers. Second, the temperature output from the MIC composition upon ignition must be verified. Third, performance of these materials when subjected to high rates of fire such as in a minigun, must be investigated.

ACCOMPLISHMENTS:

1. Bullet: The standard processes and methodologies to evaluate the toxic characteristic leaching procedures were evaluated for compatibility with obtaining the desired data and found to be insufficient. The procedures have been modified, the standard containment vessel used for these tests has been redesigned to permit introduction/collection of fluids, and this modified chamber is under construction. Preliminary Bio-Uptake studies have been completed and the results are under evaluation.
2. Primer: The initial MIC formulation has been assembled into primers in four distinct variants. Preliminary testing has been accomplished at ambient and -65 degrees Fahrenheit with moderate success at both temperatures with one variant. Optimization studies for energy release and sensitivity are ongoing. The evaluation matrix to determine ignition sensitivity versus temperature has been developed.

TRANSITION: ARDEC, the lead laboratory for the ammunition Single Manager, will work with industry to facilitate transition of results into fieldable products.

PROJECT SUMMARY

PROJECT TITLE & ID: Elimination of Toxic Materials and Solvents from Solid Propellant Components; PP-1058

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Missile Command - Huntsville, AL

PRINCIPAL INVESTIGATOR: Mr. Michael Lyons

FY 1998 FUNDS: $1420K

OBJECTIVE: The overall goal of the "Green Missile" program is the elimination of major sources of toxic/hazardous materials used in solid rocket propulsion systems. The objectives are three-fold: 1) develop lead-free extrudable and castable propellant for minimum smoke systems; 2) develop complete and clean, HCl-free, combustion of propellant; and 3) develop solventless methods for processing energetic oxidizers.

BENEFIT: Immediate benefits from the research are: 1) a lead-free formulation for HELLFIRE and the Tri-Service 2.75 rocket, solving 95 percent of the current lead emission problems; 2) an HCl-free formulation for the TITAN, solving 25 percent of the total HCl emissions; and 3) a solventless energetic oxidizer process for HELLFIRE, a solution for 60 percent of the ADN/CL-20 systems. With technology transfer to similar systems, the potential overall cost savings from the research are $1.5M from lead elimination and $3M with solvent elimination/minimization.

TECHNICAL APPROACH AND RISKS: Extrudable and castable formulations of ammonium dinitramide (ADN), CL-20, or AN, rocket motor propellants will be developed. The associated energetic polymeric binders, including thermoplastic elastomers (TPEs) developed by the Clean Agile Manufacturing of Energetics (CAME) program (SERDP Project PP-063), will also be evaluated and selected for development with the candidate formulations. Data from the characterization of the final formulations shall be compared to baseline data to determine the amount of pollution prevention obtained using the new formulation and that the user requirements are still being met. Technology demonstrations will be done for the Tri-Service 2.75 and Army's HELLFIRE systems.

Propellant formulations containing ultra-fine aluminum (UFAL) and non-halogenated oxidizers will be developed and characterized. Formulation studies shall be conducted to determine the optimum processing procedures. The combustion efficiency shall be determined as well as the identity of the combustion products to demonstrate clean burning.

A method to produce comminuted ADN, CL-20, and AN oxidizers in a size, shape, and purity suitable for propellant manufacture will be developed. Process parameters that influence the behavior of these

solvated oxidizers, when crystallized in a liquefied gas antisolvent, will be evaluated and optimized. Included in these evaluations will be the effects of atomization droplet size, nozzle configuration, oxidizer concentration, solution viscosity, and liquid surface tension on particle size and structure. Process scale-up will be demonstrated with materials to be used for the 2.75 and HELLFIRE systems. Supercritical fluid processing of energetic components will be achieved through supercritical chemistry, supercritical processing and energetic material processing. Technology demonstrations will be done with ADN/CL-20.

The technical risk associated with the research is that the alternative materials that are developed may be environmentally friendly but not have the necessary propulsion characteristics. Critical factors include particle size, bonding agent compatibility, and stability.

ACCOMPLISHMENTS:

1. For the lead-free formulation for HELLFIRE, alternatives have been identified and evaluated.
2. As a HCl-free oxidizer process for TITAN, the solventless processing systems for oxidizers were validated and the scale-up for generating pound quantities of comminuted oxidizers was completed.
3. In order to develop a solventless method for processing energetic oxidizers, solubilities studies for coating energetic materials using supercritical fluids were conducted.

TRANSITION: Program Managers/Program Executive Officers for HELLFIRE, Tri-Service 2.25 rocket and TITAN are prepared to endorse this technology when successfully demonstrated.

PROJECT SUMMARY

PROJECT TITLE & ID: Next-Generation Fire Suppression Technology Program; PP- 1059

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: National Institute of Standards and Technology

LAB: Building and Fire Research Laboratory - Gaithersburg, MD

PRINCIPAL INVESTIGATOR: Dr. Richard Gann

FY 1998 FUNDS: $3,500K

OBJECTIVE: Halon 1301, the predominant and critical total flooding fire suppressant installed in weapons systems, is no longer in production due to its deleterious effect on stratospheric ozone. The objective of this program is to develop and demonstrate, by 2004, environmentally acceptable and user-safe processes, techniques and fluids that meet the operational requirements currently satisfied by Halon 1301 systems in aircraft, ships, land combat vehicles, and critical mission support facilities. The results will be specifically applicable to fielded weapons systems and will provide dual use fire suppression technologies for preserving both life and operational assets. This effort leverages prior SERDP-funded research and the Research Development, Test, and Evaluation (RDT&E) infrastructure that has been created during the ongoing Department of Defense's (DoD's) near-term research program.

BENEFIT: The outcome of this program will be demonstrated alternatives to Halon 1301 usage that will enable DoD weapon system managers to make prudent decisions in removing their dependence on a key ozone-depleting substance in a manner that offers the least fiscal and operation barriers to implementation.

TECHNICAL APPROACH AND RISKS: The research approach consists of six parallel Technical Thrusts, closely integrated and structured to achieve specific milestones within an 8-year time frame. This approach was developed collaboratively by government, industry, and academic experts in fire science, the contributing technical disciplines, instrumentation, testing, and current Halon 1301-protected weapon systems. The six Technical Thrusts, which embody 24 separate research elements, are:

1. Risk Assessment and Selection Methodology develops a process for choosing among alternative technologies by applying modern decision-making concepts.
2. Fire Suppression Principles establish the mechanisms of flame extinguishment using detailed experimental studies and computational models leading to new approaches for fire control.
3. Technology Testing Methodologies select, adapt, and develop test methods and instrumentation to obtain data on the effectiveness and properties of new suppression approaches.
4. New Suppression Concepts define new ideas for fire suppression based on chemical and physical principles.
5. Emerging Technology Advancement accelerates to maturity a variety of processes, techniques, and fluids that are currently under development.

6. Suppression Optimization develops the knowledge to obtain the highest efficiency of each candidate technology.

This is a "living" program, representing the best current thinking for achievement of the objective, yet adaptable as the knowledge base grows. There are always risks in such an undertaking. For instance, there might be no chemicals that perform well for all the desired properties; no new fire suppression technologies might emerge; optimization principles might not improve mediocre approaches sufficiently; and lab-scale measures might not adequately predict real-scale performance. This research is designed to provide the scientific understanding to maximize the likelihood of overcoming factors.

The FY 1997 projects are:
1.a. Development of Model Fires for Fire Suppression Research
2.a. Mechanisms of Ultra-High Efficiency Chemical Suppressants
2.b. Suppression Effectiveness of Aerosols and Particles
2.d. Stabilization of Flames
3.a. Dispersed Liquid Agent Fire Suppression Screen
4.a. New and More Effective Fire Suppression Technologies Presently Conceptual
4.a-1. Development of a Self Atomizing Form of Water
4.a-2. Identification and Proof Testing of New Total Flooding Agents
4.a-8. Electrically Charged Water Mists for Extinguishing Fires
4.a-13. Flame Inhibition by Phosphorus-Containing Compounds

ACCOMPLISHMENTS:
1. Current Fire Suppression System Data: Prepared a draft report characterizing Halon 1301 fire suppression systems in representative current Army and Navy combat platforms and the type of fires these Halon systems are used to combat.
2. Viability of New Fire Suppression Technologies: Tunable diode laser system for hydrogen fluoride (HF) measurement installed, calibrated and tested in a combat vehicle at the Aberdeen Test Center, the first of a suite of advanced instrumentation for characterizing fire suppressant effectiveness under realistic conditions.
3. Suppressant Screening Tests: Constructed a prototype burner for routine determination of the flame suppression effectiveness of both gaseous and aerosol suppressants.
4. New Flame Suppression Chemistry: Completed a comprehensive literature survey of flame inhibition and flame suppression data on "superagents," chemicals that are at least as effective as Halon 1301. Additionally, began investigating the flame behavior of $Fe(CO)_5$, a (toxic) superagent , measuring the agent concentration at extinction, the emission of the flame propagation radicals OH, C_2, and CH, and the size, composition, and infrared reflectance of particulate formed during inhibition of low pressure methane/air flames inhibited by $Fe(CO)_5$.
5. Completed ozone depleting potential (ODP), global warming potential (GWP), and toxicity estimates and the development of synthetic procedures for a range of silicon, phosphorus, and amine compounds. Identified seventeen compounds (4 bromofluoroamines, 6 silicon compounds, and 7 phosphorus compounds) as having potentially acceptable fire suppression, toxicity, and environmental properties.
6. Found that dimethylmethylphosphonate (DMMP) is four times as effective as CF_3Br as a flame suppressant.

7. Better Use of Water: Prepared CO_2 hydrate as a possible means of dispersing water more effectively in a complex geometry, and found that its behavior in spray discharge is qualitatively found to be what would be expected in theory and what is needed for it to be used as a fire extinguishing agent. However, the self-atomization occurred too soon for transport into the flame, and other hydrates are being pursued.
8. New Aerosol and Powder Suppressants: Determined that potassium bicarbonate (a potent fire suppressant) particles with diameters greater than 50 μm demonstrated little in size as they passed through a flame, while smaller particles displayed a dramatic decrease in their size.
9. Better Suppressant Delivery: To determine clutter geometries most effective in stabilizing a flame, performed fire simulations for eight test geometries: four simple obstructions having the shapes of a flat plate baffle, a T-flange, a J-flange and a step and four more established by forming a cavity between pairs of the four obstructions. The preliminary results showed that the cavity formed between two steps is the most stable.

TRANSITION: This is an eight-year comprehensive research and development (science and technology) effort. Successful subprojects will be further developed within this program. "Spin offs" to various weapons systems development programs are anticipated.

PROJECT SUMMARY

PROJECT TITLE & ID: Insensitive Munitions, PP-1072

RESEARCH CATEGORY: 6.3 Advanced Development

LEAD AGENCY: U.S. Navy

LAB: Naval Surface Warfare Center - Carderock, MD

PRINCIPAL INVESTIGATOR: Dr. James Short

FY 1997 COMPLETED PROJECT

OBJECTIVE: This project had two objectives:

1. Development of benign energetic materials which provide for safer, more cost effective insensitive munitions which meet increasingly stringent environmental regulations. Both new (low environmental impact) materials and new (low environmental impact) manufacturing and disposal methods will be developed.
2. Bring together a number of modeling and simulation modules which make possible the design of a gun propellant which meets all operational requirements for military guns. Operational requirements include: manufacturing cost, life-cycle cost, performance, safety, and environmental impact. Modeling modules reflecting the needs of these operational requirements will be used by the propellant designer to make trade-offs between requirements when the requirements might lead to inconsistent or conflicting decisions.

BENEFIT: The new "green" energetic materials and manufacturing processes will reduce the adverse life-cycle impact of ordnance on the environment. The green materials will simultaneously provide higher performance energetics, reduce life-cycle cost of weapons during development, procurement, and demilitarization. The propellant modeling models will enable the propellant designer to make decisions based on inexpensive models rather than based upon expensive trial and error testings of many experimental propellant formulations.

ACCOMPLISHMENTS:

1. A hazard analysis on ammonium dinitramide (ADN) has been initiated. The task to find a more efficient synthesis method for ADN using nitronium ammonium pyrosulfate with ammonia has been investigated, but not optimized.
2. A target formulations have been defined using two binder (acrylate elastomers & compounded styrenics). The goal is to avoid use of plasticizers. The probable energetic filler is RDX.

TRANSITION: The results of this project will be integrated with the results of the Clean Agile Manufacturing of Energetics (CAME) project (SERDP Project No. PP-063).

PROJECT SUMMARY

PROJECT TITLE & ID: Tri-Service "Green" Gun Barrel - A Physical Vapor Deposition for the Application of Environmentally Safe Coatings for Gun Barrel Bore Protection; PP-1074

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Army

LAB: Benet Laboratories - Watervliet Arsenal, NY

PRINCIPAL INVESTIGATOR: Dr. John Vasilakis

FY 1998 FUNDS: $550K

OBJECTIVE: This project will develop an innovative dry (non-aqueous) process for the deposition of chromium or other materials equally suited for the bore protection of a gun barrel to replace the aqueous electrodeposition process. This novel (non-aqueous) non-polluting process is called the Cylindrical Magnetron Sputtering Process. The project will evolve the applied research and develop the appropriate technology culminating in an advanced technology demonstration addressing specific Army, Navy, and Air Force requirements in the plating of the Medium Caliber Barrels. Moreover, it will show that the work can be spun off to Large Caliber Gun Barrels and other applications including cylinders for: recoiling mechanisms, aircraft landing gear, the oil processing industry, the power generation industry, and the mining and exploration industry.

BENEFITS: Current weapon systems and those being developed or in the planning stage today will have gun tubes with chromium as a protective deposit on their interior/bore surface. This protective cover protects the bore surface against the harsh environment of the hot propellant gases, and the mechanical effects of the projectile thereby increasing the life of the gun tube. However, chromium is a heavy metal which is deposited onto the tube surface using aqueous electrodeposition. The chromic acid used in the deposition process is a hazardous substance because it contains hexavalent chrome. Hexavalent chromium, in the aqueous liquid and misting forms, is a known carcinogen which is extremely expensive to dispose of because of its toxic nature. Agencies which plate with chromium spend hundreds of thousands of dollars on environmental waste removal. An estimate of environmental costs related to the gun tube chromium plating process is about 8 percent of total costs. This value initially came from a large caliber analysis and was deemed a reasonable number, by two industrial manufacturers, to be applied to medium caliber gun tubes. For FY95 for large caliber barrels, the cost of waste water treatment and sludge removal was $2.3M. This was for only one year and does not include the cost of medium caliber gun tubes.

This program will develop a dry, environmentally clean replacement process for the existing aqueous electrodeposition chromium plating facility. All the services will benefit, including not only those who plate in-house, but also the industrial partners who are producing many of the weapons on contract.

TECHNICAL APPROACH AND RISKS: The solution to the aforementioned environmental problems is the substitution of the CYLINDRICAL MAGNETRON SPUTTERING (CMS) for the present aqueous electroplating process. CMS is a dry, environmentally clean technology capable of depositing chromium on gun tubes. It also has the flexibility to deposit other refractory metals and their alloys as well as being able to tailor the coating properties through the deposition thickness. Although the environmental focus is on chromium, alternate materials such as tantalum which will eliminate the environmental problems all together as well as providing improved bore protection will be tried. If chromium were deposited, environmental problems can still exist because a "consumable" chromium target would have to be made, most likely, by the same electrodeposition process that this project seeks to eliminate.

Initial efforts will focus on developing the facility for investigating a single medium caliber size and the parameters required for depositing a well-adhered, uniformly-coated tubular section. Once established, the facility will be sized to accept the different caliber gun tubes provided by the tri-Service partners. These will be returned to the partners for firing tests. Results of the tests will be evaluated by the coordinating laboratory in conjunction with its partners. Leveraged support is through universities, other government agencies, and industries. Some of this support is through additional funds while other support is through exchange of services. Where necessary, Cooperative Research and Development Agreements (CRADAs) will be developed if non-existent. These areas cover novel efforts in coating evaluation and coating property determination, mathematical modeling of the experimental efforts, the providing of gun tubes for coating, etc.

This is primarily still a research and development program and therefore risks exist. Although through earlier work there have been indications that this is a very viable technology, it is still to be demonstrated. FY98 will focus on test plans for the sputtering facility, such as bore size (relating to service armament platforms), fixture design and fabrication, design of experiment type test plans, and determination/testing for relevant parameters important to the cylindrical magnetron sputtering process.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: There is tri-Service support for the program and typical medium caliber barrels from each of the Services will be coated with the new process and test fired at each of their respective facilities. The program is also heavily leveraged with others from not only the environmental area, but also from gun barrel wear and erosion areas. Industry has provided information to the program regarding environmental costs and have indicated interest in applying the technology once it has been developed.

PROJECT SUMMARY

PROJECT TITLE & ID: Non-Polluting Composites for Remanufacturing and Repair for Military Applications; PP-1109

RESEARCH CATEGORY: 6.1 Basic Research

LEAD AGENCY: U.S. Army

LAB: Army Research Laboratory - Aberdeen Proving Grounds, MD

PRINCIPAL INVESTIGATOR: Dr. Bruce Fink

FY 1998 FUNDS: $692K

OBJECTIVE: The technical objective is to research, develop, and demonstrate a unique, affordable, environmentally friendly family of polymer-matrix composite (PMC) manufacturing and repair technologies for stand-alone repair of current, soon-to-be-fielded, and future Department of Defense (DoD) structures. Repair concepts and technologies will be demonstrated on three DoD-specific problems, including the design and implementation of a non-autoclave repair procedure for the oft-repaired helicopter rotor blades at Corpus Christi Army Depot (CCAD); the development, demonstration, and documentation of a repair-friendly processing method for the remanufacture of the Navy's fielding of the Advanced Enclosed Mast/Sensor System (AEMSS) including multi-functional material development; and the development of several advanced concepts for non-autoclave manufacture and repair of thin composite skins for aircraft and Army rotorcraft.

BENEFIT: This program will create technologies that enable out-of-autoclave processing as well as reduction of emissions from adhesive bonding operations. Used in tandem, these techniques can substantially reduce pollutants and waste in composite repair and remanufacturing. These technologies offer the additional benefit of significantly decreasing the need for recycling of scrap and waste materials by enabling materials to be used efficiently and the number of processing steps required for the manufacture of multi-functional PMC components (e.g., Crusader and AEMSS) to be reduced by up to 80 percent. In the AEMSS alone, cost savings in excess of $10M over the next 6-7 years are anticipated. This work will have significant 'buy-out' effects on the following requirements:

1. Hazardous materials substitution - substituting 100+ tons/yr. of thermoset adhesive on AEMSS through the co-injection process.
2. Minimization of hazardous emissions - vacuum-bag repair technologies to control and minimize hazardous effluents and alternatives to the use of adhesives in composite structure manufacturing.
3. Reduction of waste and environmentally friendly composites manufacturing - significant reduction in scrap (80 percent) in large-scale manufacturing for DoD applications such as AEMSS and Composite Armored Vehicle (CAV).

Specific benefits include the following:

a. Unlimited shelf life and elimination of associated waste.

b. Reduced-pollutant manufacturing and repair technologies enabled by new materials and curing methods.
c. Significant reduction in manufacturing waste and emissions for multi-functional composite structures.
d. Potential compliance fix for more-stringent processing-emissions standards.
e. Quantification of environmental benefits of nonautoclave, reduced-part-count, low-emission technologies.

TECHNICAL APPROACH AND RISKS: This program investigates a variety of novel composite processing and cure methods, including vacuum-assisted resin transfer molding (VARTM), the multi-resin co-injection process, electromagnetic PMC curing techniques, and novel portable radiation (ultraviolet and electron beam) cure techniques to solve pollution problems in composites remanufacturing and repair for military applications. A key to success is tight control over temperature during processing, reducing residual stresses and providing a consistent glass transition temperature (Tg) and consistent mechanical properties using recently invented composite manufacturing techniques and optimizing them for repair of complex DoD PMC structures.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: Systems of interest for the application of these novel manufacturing/repair methods and for specific demonstration of the technologies during this program include Army helicopter blade repair with the new Aviation and Missile Command and CCAD; the Navy's mast enclosure redesign, remanufacture, and repair procedure development with the Naval Surface Warfare Center; and Navy/Air Force aircraft skin non-autoclave manufacture and repair through Northrop Grumman and Science Research Lab.

PROJECT SUMMARY

PROJECT TITLE & ID: Genetic Enhancement of an Anti-Freeze Protein for Use as a Substitute for Ethylene Glycol for Aircraft Deicing; PP-1110

RESEARCH CATEGORY: 6.1 Basic Research

LEAD ORGANIZATION: U.S. Air Force

LAB: Air Force Research Laboratory - Tyndall AFB, FL

PRINCIPAL INVESTIGATOR: Dr. John Henry - Aspen Systems, Inc.

FY 1998 FUNDS: $206K

OBJECTIVE: Traditional anti-icing/deicing agents are either propylene or ethylene glycol. Glycols are effective in lowering the freezing point of water mixtures by the phenomenon of freezing point depression based solely on the molal concentration. The key environmental concerns with respect to use of ice control fluids are biological oxygen demand (BOD) loading and toxicity (human/mammalian and aquatic) resulting in extensive costs associated with the collection and cleanup associated with their use. For example, at Griffith AFB, NY, the use of glycols as a deicing fluid for aircraft has resulted in ground-water cleanup programs costing over $8.2M. Additionally, an Air Force policy has been issued banning future purchase of ethylene glycol.

The need to develop environmentally benign deicers is particularly urgent because of recently passed Environmental Protection Agency (EPA) regulations that are making the continued use of current deicers prohibitively expensive. These regulations require the construction of on-site collection and treatment facilities for the spent deicing chemicals. The immediate ramification of these regulations is that waste deicing fluid runoff will be classified as a non-storm water discharge which must have a low BOD, and hence this discharge requires an individual permit if it cannot be eliminated. In addition, it will be necessary to sample the storm water for deicing chemical content and develop a storm water pollution prevention plan.

In order to meet this challenge, this project proposes to produce novel deicing and anti-icing agents using naturally occurring antifreeze proteins, which have a very low BOD compared to the current agents. Initial research has indicated that *Dendriodes canadensis* protein found in insects produces a freezing point depression that is 300 to 500 times the predicted value based on its molal concentration due to non-colligative properties. This project proposes to genetically alter the *Dendriodes canadensis* antifreeze protein gene in order to enhance the freezing point depression capabilities and therefore increase its usefulness and value as an aircraft deicing/anti-icing agent.

BENEFIT: The implementation of collection and treatment facilities translates to significant cost for the Air Force. Therefore the timely introduction of a nontoxic, low BOD deicer is particularly urgent. Aspen Systems deicing agent is based on a naturally occurring protein that will be nontoxic and have a low BOD.

When the cost of production of these proteins is calculated in conjunction with the lower management and litigation costs of their use, they will be a very economically viable and environmentally beneficial alternative to the current deicing agents. The production of an environmentally benign deicing agent by this program will be essential to the deicing of both civilian and military aircraft because it eliminates the high costs and associated danger of environmental pollution from this essential area of aircraft safety.

TECHNICAL APPROACH AND RISKS: Aspen Systems proposes to genetically alter the gene of its proprietary *Dendriodes canadensis* Antifreeze Protein in order to enhance the freezing point depression capabilities and therefore increase its usefulness and value as a wing deicing/anti-icing agent. The first year of this program (FY98) will be broken down into five tasks. These include: DNA Synthesis; Gene Mutation & Bacterial Cloning; DNA Sequencing; Yeast Cloning; and Initial Protein Expression.

Successful completion of the first year of this program will be the cloning, selection, and confirmation of the mutated antifreeze gene. We will also complete the initial expression of several of these mutated *Dendriodes canadensis* antifreeze proteins. The purification as well as the continued enhancement of the expression of the mutated proteins will occur within the second year of the program.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: All Services and the commercial airline industry will be apprised of initial results. Successful candidates may be further tested by Service programs.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmentally Advantaged Substitutes for Ethylene Glycol for Aircraft Ice Control; PP-1111

RESEARCH CATEGORY: 6.2 Applied Research

LEAD ORGANIZATION: U.S. Air Force

LAB: Air Force Research Laboratory

PRINCIPAL INVESTIGATOR: Ms. Carolyn Westmark - Foster-Miller, Inc.

FY 1998 FUNDS: $688K

OBJECTIVE: The technical objective of this program is to develop a high performance, environmentally benign aircraft anti-icing fluid which can be safely released to the environment without capture, control, and post-treatment of the runoff. Specific objectives are to: (1) develop a molecular modeling approach which allows for prediction of non-Newtonian viscosity behavior of materials based on their chemical structure; (2) develop a non-toxic, non-Newtonian thickening agent with enhanced performance capabilities for anti-icing fluids, particularly extended holdover times; (3) select low environmental impact additives for performance enhancement; (4) demonstrate that the anti-icer formulations are compatible with military aircraft materials and weapons systems; (5) demonstrate the ability of the anti-icing formulations to prevent ice formation for extended periods of time in simulated adverse weather environments; (6) develop encapsulated enzyme additives which exhibit controlled release properties and actively degrade the anti-icer formulation at reduced temperatures; (7) predict the water quality impact of new anti-icer formulations at actual airfield sites using computer modeling and laboratory analysis of key environmental parameters; (8) determine any potential health/safety risks of anti-icing formulations; and (9) develop cost-effective anti-icing formulations by screening out excessively costly materials throughout the testing program. The most promising freezing point depressants from an earlier Air Force funded Small Business Innovation Research (SBIR) Phase I program will be used as a basis for anti-icer formulations.

BENEFIT: The project benefits include: (1) a drop-in, fully characterized environmentally advantaged replacement for ethylene and propylene glycol based aircraft deicing materials; (2) elimination of the cost of capture/treatment of effluent from aircraft deicing processes; (3) reduction of material cost for aircraft deicing processes (since high efficiency fluids require less material usage); and (4) increased flight safety and mission readiness. Additionally, this project will provide a model for non-Newtonian viscosity prediction based on the chemical structure of compounds, a self-remediating anti-icing fluid formulation, and a model for predicting the impact of changes in ice control material formulation on runoff water quality at actual airfields.

TECHNICAL APPROACH AND RISKS: The Foster-Miller strategy to develop environmentally advantaged aircraft ice control materials involves three key elements: (1) substitution: identifying ice control material formulations which are inherently less damaging to the environment than currently used

materials; (2) source reduction: developing efficient, high performance fluids which require less material to accomplish the objective of protecting aircraft surfaces from ice accretion; and (3) "in-situ remediation": developing "self-remediating fluids" which degrade to less harmful products prior to entering the ecosystem by means of a triggerable reaction.

Foster-Miller is already pursuing the development of inherently environmentally advantaged freezing point depressants (FPDs) in a U.S. Air Force (Air Force Laboratory) sponsored SBIR program. This SERDP sponsored project focuses on the development of anti-icing fluids, which will incorporate the FPDs developed under the SBIR program. Anti-icing fluids offer source reduction benefits as compared to deicing fluids since less material is wasted on runoff and overspray and the material remains on the aircraft surfaces until takeoff to provide long lasting protection against icing, thus avoiding re-application of fluids. In addition, these anti-icing fluids offer advantages in terms of enhanced flight safety and mission readiness.

In this program, Foster-Miller will develop environmentally advantaged anti-icing fluids using all three elements of this strategy. This will be accomplished by: (1) identifying a wide range of candidate formulations, ranking them based on their predicted performance, environmental impact, and cost using computer model-aided screening, multi-tiered testing, and expert advice from aircraft deicing fluid manufacturers; and (2) developing high performance anti-icing fluids which require less material than current fluids to protect the aircraft from icing. The key to this approach is Foster-Miller's development of a high performance, environmentally benign thixotrope; and development of a gel-encapsulated, FPD-degrading enzyme system which will be incorporated into the anti-icing fluid and released on demand to initiate the degradation of the fluid into harmless byproducts.

During the first year of the program (FY98), Foster-Miller will identify non-Newtonian thixotropic agents and develop a model which predicts non-Newtonian viscosity of a compound based on its chemical structure. This model will be used to identify candidate thixotropic agents and synthesize new thixotropes with enhanced performance compared to currently available materials. Thixotropes will be added to freezing point depressant materials and their rheological behavior will be evaluated. The combination of thixotrope and freezing point depressant will be subjected to the first tier (screening) series of tests of performance, toxicity, materials compatibility, and cost. In addition, development of an enzyme which is active in degrading the FPD will be initiated in FY98.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: All Services and the commercial airline industry will be apprised of initial results. Successful candidates may be further tested by Service programs.

PROJECT SUMMARY

PROJECT TITLE & ID: Recycle and Reuse of Industrial Rags Using Liquid CO_2 and Surfactant Additives as a Cleaning Agent; PP-1112

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: Environmental Protection Agency

LAB: National Risk Management Research Laboratory

PRINCIPAL INVESTIGATOR: Mr. Charles H. Darvin

FY 1998 FUNDS: $439K

OBJECTIVE: The technical objectives of this proposal are to develop, demonstrate, and evaluate a LCO_2 fabric cleaning technology for application to the cleaning of Department of Defense (DoD) generated hazardous cleaning rags. The most promising candidate technology to accomplish this objective is the use of liquid CO_2 (LCO_2) with surfactant additives. The economics of LCO_2/surfactants systems will be critically dependent on recovery and separation of surfactants, CO_2, and contaminants. LCO_2 has no associated environmental impacts and few safety concerns: it is non-hazardous, non-flammable, non-ozone-depleting, and non-toxic. Thus, there are none of the concerns which might be found with conventional cleaning technologies using organic solvents or aqueous solutions. Also, a system using liquid phase CO_2 is expected to be less destructive to fabrics. Finally, there is no pollution control process cost associated with achieving environmental compliance using the potential LCO_2 technology.

The initial focus of the program will be using CO_2 in the liquid phase, and not supercritical phase, unless research directions dictate a technical efficiency in the supercritical. Some studies outlined in the references on the use of CO_2 indicate that the use of CO_2 in the liquid phase will present a more efficient system for the cleaning of fabrics. A system operating in the liquid phase will present a more efficient system for the cleaning of fabrics. A system operating in the liquid phase is expected to be less destructive to fabrics and clothing as well as to attachments, such as buttons on work clothing.

BENEFIT: If contaminants contained on the rags can be removed successfully and collected, the rags can be recycled back to the operation and will eliminate rags as a source of hazardous waste pollution from DoD and related facilities.

A 1996 study, conducted for the Chief of Naval Operations, found that a minimum of $5M in rags are procured each year by the U.S. Navy for U.S. based facilities. This study did not include shipboard or foreign facilities. A major part of these rags is disposed of as hazardous waste at a disposal cost estimated to be in excess of $7M. This estimate results in an annual rag procurement and disposal cost for the U.S. Navy in excess of $12M. Rags generated on ships and at foreign facilities are required by many host countries to be transported back to the U.S. for disposal. It is reasonable to assume that an equal amount of rags are procured and disposed of by the remaining military Services. This would result in an additional

$24M in rag procurement and disposal cost for U.S. military services. The estimated cost savings in rag procurement and disposal for all U.S. military Services is therefore estimated at more that $360M over a 10-year period.

TECHNICAL APPROACH AND RISKS: The major objective during the FY98 Phase I portion of the program will be to conduct and complete research to design and synthesize LCO_2 compatible amphiphilic surfactants. The proposed surfactants will have a micelle-forming capability to emulsify lipophilic contaminants within a continuous LCO_2 phase. These surfactant systems must be applicable to a broad range of contaminants which will be defined by the potential users.

The chemical design philosophy of the candidate, micelle-forming surfactants to be synthesized during the Phase I effort is based upon results of surfactant research investigations recently published by Dr. J. DeSimone at the University of North Carolina. To date, two nonionic, amphiphilic copolymers have been synthesized. Accordingly, families of these amphiphilic surfactants will be tailored to meet the specific requirements necessary to emulsify and displace the contaminants typically found in industrial rags.

The use of CO_2 in the supercritical phase is a proven technology for certain applications such as precision metal cleaning and solid waste decontamination, or where the contaminant is primarily light organic compounds and non-particulate. However, LCO_2 has yet to be proven for fabric cleaning, or for military cleaning requirements which contain heavy molecular weight organic compounds, inorganic salts, metal oxides, proteins, and solid matter. The FY98 Phase I effort will include the following specific tasks:

(a) Rag and fabric characterizations and contaminant identification: sample rags will be secured and analyzed to identify probable contaminants that may be found in typical industrial cleaning rags.
(b) Define cleanliness specifications for recycled wipe rags: these studies will provide speciation data for which the surfactants will be designed and tailored.
(c) Synthesize and tailor surfactants: the surfactant synthesis and formulation studies will be conducted at participating university laboratories.
(d) Laboratory testing: extensive laboratory testing of candidate surfactants and blends will be conducted to identify the most appropriate and efficient surfactant candidate for further bench scale testing.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: The military Services will be apprised of initial results. Success may lead to cooperative Service programs.

PROJECT SUMMARY

PROJECT TITLE & ID: Sol-Gel Technology for Low VOC, Non-Chromated Adhesive & Sealant Applications; PP-1113

RESEARCH CATEGORY: 6.2 Applied Research

LEAD AGENCY: U.S. Air Force

LAB: Air Force Research Laboratory - Wright Patterson Air Force Base, Dayton, OH

PRINCIPAL INVESTIGATOR: Mr. James Mazza

FY 1998 FUNDS: $665K

OBJECTIVE: The primary objective of this project is develop and transition to the Department of Defense (DoD) and other organizations processes that eliminate the volatile organic compounds (VOCs), chromates, and strong acids typically found in the metal surface treatment and priming steps conducted prior to application of adhesives and/or sealants. Secondary objectives are the reduction of hazardous wastewater streams associated with current processes and improved performance compared to these processes.

This project will develop, evaluate, and field demonstrate nonchromated, zero VOC sol-gel processes for adhesive and sealant applications. The sol-gel processes developed will replace the current approaches that are high-VOC and/or chromate. They will also eliminate the current use of strong acids and reduce the waste streams associated with the existing processes.

BENEFIT: Development of new non-chromated, zero-VOC adhesive and sealant surface preparation and primer technologies will have a major impact on both cost and performance of military and commercial aircraft. Eliminating VOCs and chromates from these processes will result in considerable cost savings due to avoiding the need for hard controls and/or fines for non-compliance. These hard controls are mandated by Federal, state, and local agencies [the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), California's Air Quality Management Districts (AQMD), etc.] through regulations such as the Clean Air and Water Acts, National Emission Standard for Hazardous Air Pollution (NESHAP), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and Resource Conservation and Recovery Act (RCRA) along with local EPA and AQMD rules. At Naval Depot (NADEP) North Island alone, the installation of VOC-control equipment for these processes is expected to cost $15M and the installation of chromate control equipment is expected to cost $2-3M, with operation costs of approximately $250K per piece of equipment annually. However, the majority of repairs at NADEP North Island are conducted on aircraft; thus, a mandate for hard controls will incur additional costs for removal of parts and increased aircraft downtime. Consideration of cost savings from other NADEPs, U.S. Air Force Air Logistics Centers (ALCs), Army depots, and commercial usage will multiply these cost avoidance figures many-fold.

Additionally, the new sol-gel processes are expected to provide increased bondline strength and/or durability for many applications; this will improve aircraft performance, decrease downtime and maintenance labor hours associated with reworking poor repairs, and enhance operational readiness.

TECHNICAL APPROACH AND RISKS: This project will build on recent work using sol-gel technology to deposit thin organic-inorganic coatings on metal surfaces to develop good adhesion between the metal and subsequently-applied polymers (primer, adhesive, or sealant) via covalent chemical bonding. A main feature of the effort is the extensive leveraging of previous, ongoing, and proposed research.

This project is divided into four tasks (three adhesive bonding and one sealant adhesion promoter/primer).

1. The goal of this task is to find an environmentally friendly pretreatment/primer system that can be implemented in the near term by optimizing a sol-gel surface preparation that is compatible with experimental waterborne adhesive bond primers. This will be accomplished by sol chemistry optimization and by developing application procedures with emphasis on the surface activation drying/cure steps. Epoxy adhesives will be the primary focus, although polyimides may also be evaluated for titanium.
2. This task will develop a one-step process that combines the adhesive primer and sol-gel surface treatment into one consolidated interfacial layer. Findings regarding the important process variables identified in Task 1, such as surface activation for the various metal alloys, will be used to develop an application procedure. This approach will eliminate the need for a separate primer step. It also has the potential to eliminate or minimize the number of different primers now used for different service temperature applications. The interface between adhesive and primer, a potential weak link, still present with the near-term Task 1 approach, would be eliminated.
3. This is a relatively small task that will be initiated in FY99, and will evaluate the sol/primer mixtures of Task 2 as traditional adhesive primers. The leading low-VOC primers, now on the verge of qualification, will be used without their chromate constituents. With the presence of the sol-gel solution to form covalent bonds to the aluminum oxide surface generated by PAA (phosphoric acid anodize), it is hoped that the non-chromated primer formulations will perform acceptably.
4. This task, which will be initiated in FY99, will leverage the sol-gel work for adhesive bonding to develop adhesion promoters for sealant operations. The highest priority area will be replacing the high-VOC primers used with silicone sealants with a zero-VOC sol-gel alternative. A second priority will be to develop a universal adhesion promoter for polysulfide and polythioether sealants to promote adhesion between these sealants and various substrates as well as adhesion between the two sealant types. The latter case will be beneficial for repair scenarios where one sealant is used over the other. This would allow more use of polythioethers over existing polysulfides in more applications. The polythioethers do not contain manganese (potentially hazardous) as do polysulfides.

ACCOMPLISHMENTS: This is a FY 1998 New Start.

TRANSITION: Further testing at NADEPs, Air Logistic Centers, and Army depots is anticipated after initial successes are achieved.

APPENDIX E
FY 1999 Statements Of Need

Cleanup

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STATEMENT OF NEED FOR FY99 SERDP CLEANUP NEW START

NOVEL SYSTEMS FOR THE DETECTION AND IDENTIFICATION OF BURIED UNEXPLODED ORDNANCE

OBJECTIVE: The primary focus of this need is to continue the process of identifying and developing innovative sensor systems and to integrate sensing technologies with high-performance sensor fusion and signal-processing algorithms for enhanced detection, location, and discrimination of buried unexploded ordnance (UXO) under a wide range of environmental conditions.

BACKGROUND: Unexploded ordnance may be found in the surface, subsurface, and marine (near-shore and deep-water) environment. The result of war, military training, and weapons-testing activities, UXO presents a threat to active installations seeking to manage and clean their ranges, to sites designated for base realignment and closure (BRAC), and to Formerly Used Defense Sites (FUDS).

In the United States, the UXO problem results primarily from weapons development and training activities, including live-fire testing and training. Current estimates indicate that 11 million acres of land potentially contain UXO.

To date, Department of Defense (DoD) funded research and development has been directed primarily to the countermine missions associated with combat operations or operations other than war. The primary thrust of the research and development described by this SON focuses on UXO clearance in noncombat situations, e.g., environmental cleanup. Proposals related to mine detection or clearing will not be evaluated. The identification of UXO represents a substantial technical challenge to the effective cleanup of many DoD sites. The UXO problem is found on all categories of DoD sites: Installation Restoration Program, BRAC, and FUDS. UXO detection is identified in the top three requirements by the Army and the Navy. UXO is found in the surface, subsurface, near-shore, and deep-ocean environments. Each of these environments offers unique challenges. To date, research and development funding for UXO identification technologies has been fragmented and has stressed the demonstration of systems rather than UXO-specific technology development.

STATEMENT OF NEED FOR FY99 SERDP CLEANUP NEW START

NONINTRUSIVE METHODS FOR DENSE, NON-AQUEOUS PHASE LIQUID (DNAPL) SOURCE ZONE IDENTIFICATION

OBJECTIVE: This statement of need seeks innovative technologies to detect, locate, quantify, and determine the horizontal and vertical extent of DNAPLs (ganglia and free-product phases) in the subsurface environment. Emphasis is on ***nonintrusive*** technologies for identification of DNAPL source zones. It focuses on innovative solutions and approaches that would ideally provide the desired information in real-time and in an easily interpretable format rather than enhancements or modifications of existing technologies. Efforts will complement or interact with other research in this area of sensor development.

BACKGROUND: Scientists and engineers are increasingly recognizing that DNAPL contamination is a very serious, widespread problem, without a ready, economical solution. One study found that up to 85 percent of Superfund sites have contaminated groundwater, and about 75 percent of those are contaminated with DNAPLs. Currently there are no acceptable, cost-effective methods for accurately locating, removing or treating DNAPLs. Successful remediation requires that source areas be located and cleanup initiated at the concentrated source to be economically feasible. Techniques for locating DNAPL sources and accurately estimating their mass are critical to cost-effective cleanup. Being immiscible with and denser than water, DNAPLs migrate downward when spilled on the ground and can accumulate below the water table. One widely used, but for the most part inaccurate, concept is the "pool of DNAPL" sitting on top an aquitard. This simple description implies that the DNAPL could be easily located and extracted, but this is rarely the case. A more realistic concept is "DNAPL ganglia," micro-scale globules dispersed throughout the soil matrix's interstitial space. The DNAPL may remain in the vadose zone or migrate below the water table. It may adsorb on, or absorb in, soil materials and may volatilize to soil gas. Any of these sources may contaminate the groundwater. Consequently, DNAPLs are difficult to locate and remove, and transport is complex, involving many interacting forces. Once in the subsurface, DNAPLs are long-term sources of groundwater contamination and may persist for centuries.

The anticipated products from these efforts are technologies that can detect and delineate subsurface DNAPLs at contaminated sites, which will lead to more cost-effective characterization and remediation of DNAPL contaminated sites. Besides the USAF, the Army and Naval Facilities Engineering Command will use the developed technologies at other military installations. There are also potential users in private industry involved in the manufacturing and use of degreasing compounds and DNAPL-related chemicals.

STATEMENT OF NEED FOR FY99 SERDP CLEANUP NEW START

IN-SITU PASSIVE TREATMENT TECHNOLOGIES FOR ORGANICS- AND/OR METALS-CONTAMINATED GROUNDWATER

OBJECTIVE: The primary emphasis of this need is to research and develop passive treatment technologies. Gaining acceptance as a cost-effective remedial action alternative for a variety of site conditions, passive treatment concepts are generally bounded by the limited variety of available materials. There continues to be a number of issues related to passive treatment technologies, such as biological fouling, capacity, efficiency, life cycle costs, etc. Considering these issues, research and development activities will be conducted at the bench, laboratory and small field scale to develop passive treatment systems for organics and/or metals contaminated groundwater.

BACKGROUND: Cleanup of contaminated groundwater contaminated with heavy metals, solvents (including chlorinated and nonchlorinated organics), explosives and energetics, other organics (pesticides and PCBs), and hydrocarbons is often difficult and can be prohibitively expensive or technically infeasible. Further, the cost of remediation efforts that employ ex-situ treatment (pump-and-treat, dig and haul, etc.), active in-situ treatment (oxygen/air/substrate injection), or stabilization (addition of chemical stabilizers) technologies usually increases exponentially as the heterogeneity of the subsurface increases. This is particularly true at sites where 1) contamination is extensive but concentrations are low, 2) access to the soil and groundwater is difficult due to restricting surface structures or uses, or 3) local restrictions forbid implementation of other available remedial technologies.

STATEMENT OF NEED FOR FY99 SERDP CLEANUP NEW START

PREDICTIVE BIOLOGICAL ASSESSMENT USING TOOLS AND TECHNIQUES FOR ECOLOGICAL RISK

OBJECTIVE: The primary emphasis of this need is to develop remediation tools and response analysis techniques that would enhance/facilitate the development of technically defensible and cost-effective environmental risk assessment methodologies used to measure or quantify ecological impacts of hazardous waste cleanup. The main objective of this need is to develop risk-based assessment methods, tools, and technologies to help establish "how clean is clean or should be clean" that would result in a significant reduction in Department of Defense (DoD) cleanup and disposal costs.

BACKGROUND: There are nearly 17,000 sites on DoD installations potentially requiring environmental cleanup. The challenges facing those involved in cleanup include distinguishing those sites that pose significant environmental risks from those that pose little risk, prioritizing contaminated sites by the degree of risk posed, quantifying the risks at each site, and developing appropriate remedial actions and cleanup goals where appropriate. Risk assessment provides a logical framework for making such decisions.

Over the last 10 years, risk assessment methodologies have been developed for characterizing environmental risks. When applied effectively, these efforts have provided useful descriptions of risk. The effectiveness of these methods can be expanded by research directed at problems particularly relevant at DoD installations.

Screening methods must be developed for military-unique compounds that will permit rapid and cost-efficient screening evaluations of the potential for media to produce toxic effects in ecological and human receptors. The development of such methods is limited in part due to the paucity of whole organism dose-response information for military-unique compounds. Technically sound screening techniques should allow risk assessors to quickly, and at low cost, distinguish sites with low and high potential for risk. Such techniques should also include methods for dealing with complex mixtures of contaminants. Such mixtures contain many contaminants that may interact so as to affect toxicity. Such mixtures predominate at DoD installations.

STATEMENT OF NEED FOR FY99 SERDP COMPLIANCE NEW START

METHODS OF CONTROLLING FINE PARTICULATE MATTER

OBJECTIVE: The focus of this program is to develop new emission-control technologies for airborne particulate matter from combustion sources with strong emphasis on particulate matter less than 2.5 microns (PM2.5). This technology is required to control fine particulate matter (PM) in air as may be emitted from combustion sources such as jet engines exhaust during tests and operations, ground vehicle and equipment operation, and/or boilers (gas discharges). The technologies will be subject to size and weight limitations of the weapons system or facility to meet Department of Defense (DoD) strategic mobility requirements and federal and local air quality standards of the Clean Air Act Amendments (1990). It should be understood that no one technology is expected to address all possible sources of particulate matter.

BACKGROUND: PM is a criteria pollutant regulated by the National Ambient Air Quality Standards (NAAQS) established by the Clean Air Act (CAA). The particulate NAAQS has specified is PM10 (particles smaller than $10\mu m$ in diameter), but a second standard, applicable to particles smaller than 2.5 μm (PM2.5), is being imposed. DoD's principal sources of airborne particulate matter emit a distribution whose average size is considerably smaller than 2.5 μm, so the proposed PM2.5 standard will constitute a drastic lowering of the effective regulatory limit for DoD's industrial processes. A DoD research and development (R&D) goal is to demonstrate zero fugitive emissions from facilities (Defense Technology Area Plan - Chapter V - Materials and Processes, 1997).

Though most particulate matter concerns are centered around emissions from stacks and engine exhausts, there are situations when particulate matter can occur from grinding and chipping in confined spaces. Many times proper ventilation is not feasible in its present bulky form to provide proper ventilation and dust control. Technologies to address this need are not a part of this statement of need.

Less expensive treatment strategies are needed for waste streams that either can not be entirely eliminated by pollution prevention efforts or as an interim solution until a suitable material substitution can be found and approved. Although there are many commercial technologies, mature and emerging, for treating air emissions, reducing the costs of these systems or developing new less costly systems will enable the Service's facilities to maximize their resources.

At present, carbon filters are used as are other filter types (paper and organic-based) to mitigate the situation. There are also several R&D efforts to use biological filters to reduce the volatile organic compound emissions, but again these require a prefilter to capture particulate matter that may clog the active filter. This activity will provide cost-effective, best-available control technologies which would be composed of mechanical/chemical capture/destruction devices.

STATEMENT OF NEED FOR FY99 SERDP
COMPLIANCE NEW START

OIL/WATER SEPARATORS

OBJECTIVE: The focus of this program is to develop innovative technologies to separate oil from water while processing wastewater generated by Department of Defense (DoD) weapons and support systems. The oil/water separators that are presently in use rely on old technology in order to effectively separate oil mixed with waters. The oily components may contain sludges consisting of organics, particulate matter, and, in some cases, heavy metals. This sludge interferes with the ability of the separator to remove oil and increases maintenance requirements. The treatment of the sludge is the subject of another Statement of Need.

BACKGROUND: The DoD has made a commitment to eliminate all polluted wastewater discharge from ships and to exceed the MARPOL criteria worldwide. This is part of the environmental quality enhance effort by the DoD as provided in the Defense Technology Area Plan, the strategy plan for research and development within the DoD. One of the pieces of equipment, that plays a major role in this effort to separate oils from water and allow the water to be discharged into the environment, is the oil/water separator. Only through the use of this and other waste treatment equipment and can the Navy attain to meet its goal of unencumbered operations of ships and submarines worldwide and the other Services be allowed to operate their bases. The DoD currently uses hundreds of oil/water separators (OWS) for a variety of applications to remove oil from aqueous streams. There are four major applications of separators within the DoD:

1. Wash rack and maintenance facilities and central vehicle wash facilities
2. Shipboard for bilgewater treatment
3. Aircraft washdown
4. Industrial Waste Treatment Plants (IWTPs)

These separators are primarily of the gravity and gravity/coalescence types. The separators are generally simple in construction and operation. The oil-contaminated residue often contains particulate matter, biological matter, heavy metals, and other contaminants. These contaminants can lead to excessive wear of the mechanical type of separators.

STATEMENT OF NEED FOR FY99 SERDP COMPLIANCE NEW START

TREATMENT OF OIL/WATER SEPARATOR SLUDGE

OBJECTIVE: The focus of this program is to develop innovative candidates for environmentally benign, non-labor-intensive methods to treat oil-contaminated oil/water separator sludges. Separator sludge contains organics, particulate matter, and, in some cases, heavy metals. In gravity separators it accumulates in the bottom of the separator and in coalescent separators it also accumulates on the coalescing media. This sludge interferes with the ability of the separator to remove oil and increases maintenance requirements. While treatment of the sludge is the primary focus of this work, volume reduction of heavy metal contaminated sludge is also of interest. Primary focus shall be given to on site treatment of sludge from separators. In addition, methods to easily remove sludge from separators with subsequent treatment also will be developed. Technologies to separate oil from water are the subject of another Statement of Need.

BACKGROUND: The Department of Defense (DoD) has made a commitment to eliminate all polluted wastewater discharge from ships and to exceed the MARPOL criteria worldwide. This is part of the environmental quality enhance effort by the DoD as provided in the Defense Technology Area Plan, the strategy plan for research and development within the DoD. One of the pieces of equipment, that plays a major role in this effort to separate oils from water and allow the water to be discharged into the environment, is the oil/water separator. Only through the use of this and other waste treatment equipment and can the Navy attain to meet its goal of unencumbered operations of ships and submarines worldwide and the other Services allowed to operate their bases. The DoD currently uses hundreds of oil/water separators (OWS) for a variety of applications to remove oil from aqueous streams. These separators are primarily of the gravity and gravity/coalescence types.

Separators, while simple in construction and operation, require periodic cleaning to remove sludge which accumulates at the bottom of the separator or, if used, on the coalescent media. This oil-contaminated sludge often contains particulate matter, biological matter, heavy metals, and other contaminants. For gravity-based separators, sludge is physically removed from the base of the separator and transported to a separate facility for treatment and disposal. For coalescing type separators, the separator must be opened, the coalescing media removed and the sludge physically extracted. This often results in the production of large volumes of oily rags, which must be disposed of separately.

STATEMENT OF NEED FOR FY99 SERDP CONSERVATION NEW START

CULTURAL RESOURCES MANAGEMENT DETECTION AND EVALUATION TECHNOLOGIES

OBJECTIVE: The objective of this statement of need (SON) is to improve the identification and assessment of prehistoric, historic, and traditional cultural properties and sites on Department of Defense (DoD) and Department of Energy (DOE) lands. There is a need to identify, develop, and integrate advanced and emerging technologies to more efficiently and cost effectively identify and evaluate cultural resources. The product(s) resulting from this SON should fuse such tools or prototypes that will allow for the effective prediction of sites and provide noninvasive tools to adequately assess the significance of these sites. This should include tools to explore the near surface substrates within the context of the larger remotely sensed spatial and spectral landscape, as well as harness rapid and more efficient surveying, mapping, recording and data analysis procedures. It should purposely and resourcefully exploit available and new digital information from whatever sources that may be useful for solving cultural resource management requirements. These requirements include DoD responsibilities to manage resources subject to the Native American Graves Protection and Repatriation Act and traditional cultural properties and historic features routinely considered in the National Historic Preservation Act. The product(s) should harness the data handling capabilities and analytical power of geographic information systems. The design models needs to be compatible and ideally modular for incorporation with other installation investments in land and training range management technology.

BACKGROUND: Federal agencies must be fully responsive to the legal requirements for cultural resource management. Millions of acres of DoD and DOE lands have not been surveyed and thousands of potential sites have not been assessed. However, conventional survey and significance, and mitigation techniques to comply with legal requirements involve time consuming, labor intensive, and unnecessarily destructive excavation. Given current budget climates, traditional conventional means to identify and assess cultural resources are potentially cost prohibitive. In addition, new and unresolved challenges exist for the assessment, evaluation and treatment of traditional cultural properties and human interments (burials). Enhanced technologies are required to meet cultural resource challenges now and in the future. Effective techniques, incorporating geomorphologic information to predict the probability of sites are needed.

Evaluation and development of new procedures, such as geophysical prospecting, which provide dramatic improvements in assessing and evaluating cultural resources and minimizing excavation are needed.

Without reliable, cost effective methods to assess sites, there is continual risk of cost delays in training, testing, and construction due to legal requirements that consider all unassessed sites eligible for listing and protection. In addition, without better technologies to predict undiscovered site locations, the military cannot reduce the risk of inadvertent discovery of significant sites and/or protected human remains. Review of legal awards against DoD in FY90 and FY91 indicate that over $10M was lost in penalties primarily due to the absence of baseline data on cultural resource information. This loss was a compilation of fines and delays in construction/training activities due both to inadequate assessment of archeological sites and to inadvertent discovery of sites that required significance assessment.

STATEMENT OF NEED FOR FY99 SERDP CONSERVATION NEW START

MITIGATION/REHABILITATION OF DAMAGE CAUSED BY MILITARY TRAINING AND TESTING IMPACTS

OBJECTIVE: The thrust of this statement of need (SON) is two-fold: (a) to focus on innovative technologies for mitigation and/or rehabilitation of damage resulting from military training and testing impacts and (b) to identify rehabilitation and maintenance techniques that will provide general improvement of the resiliency of ecosystems for long-term sustainment of lands.

BACKGROUND: Military training and testing often causes damage to land, vegetation, habitat (terrestrial and aquatic/marine) and other environmental components. Because these activities continually recur, mitigation and rehabilitation measures must regularly be employed to ensure ongoing sustainability of military training and testing resources, as well as to support Department of Defense (DoD) environmental stewardship responsibilities. In some cases, similarities between military and non-military impacts allow the adoption of mitigation/rehabilitation techniques developed for civilian use. In many cases, the military impacts and land use requirements are sufficiently unique that special measures must be developed or adapted for mitigation and rehabilitation. In yet other cases, even when the military impact is not unique, the relative urgency of supplying mitigation/rehabilitation measures is much higher for the DoD than the civilian sector, so that DoD must drive the development of these capabilities to meet its needs in a timely fashion.

Conceptually, the sustainability of lands for continued use requires short- and long-term techniques. Damage caused by the military use of lands can be direct and subtle. Direct damage results in immediate or short-term removal of vegetation, subsequent gullying, and potential impacts on water quality. Continued damage and natural ecosystem processes can ultimately affect ecosystem structure and functions, e.g. habitats, biogeochemical cycles, water quality, etc. Land and ecosystem rehabilitation and restoration requirements for direct damage is urgent, on relatively frequent intervals, requires intensive action, and driven by mission needs and costs. Long-term rehabilitation and restoration, i.e. the latter case, may or may not be urgent, takes into account the resiliency and changes of ecosystems, may be achieved by less intensive action, and involves temporal and spatial scales that are dictated by ecosystem dynamics. Work proposed for this SON should identify land rehabilitation techniques that apply to either or both cases. Differences (or similarities) in restoration approach need to be assessed, and rehabilitation design and implementation actions that are most appropriate when considering both short- and long-term needs and/or the combination of the two need to be determined. That is, the short-term needs to train realistically and minimize environmental impact today, and the long-term needs to sustain ecological resources for future use, i.e. allowing the ecosystem to more effectively withstand long-term impacts and recover more quickly.

STATEMENT OF NEED FOR FY99 SERDP POLLUTION PREVENTION NEW START

MECHANISMS OF COATINGS DEGRADATION

OBJECTIVE: The objective of this program is to acquire a fundamental understanding of the mechanisms by which coatings degrade. These mechanisms refer to the changes in chemical, physical and mechanical properties which occur in coatings during their lifetime which contribute to the loss or degradation of performance. Performance may be in terms of signature, weather protection and/or corrosion abatement, etc. This program should result in a basic understanding of degradation mechanisms as well as recommended approaches for the development/optimization of new coating systems and realistic life prediction techniques.

BACKGROUND: Currently, there are no known environmentally acceptable, high performance coatings with extended durability. In addition, little is understood about the mechanisms of paint degradation. In order to meet Department of Defense (DoD) coating requirements beyond the year 2000 in terms of environmental compliance, and to achieve even modest performance, in terms of durability and corrosion protection, substantial advances in the current state-of-the-art of environmentally acceptable, high performance coatings must be undertaken.

Historically, materials and processing technology for organic coatings has been based on a formulation chemistry involving extensive utilization of volatile organic compounds (VOCs) and hazardous air pollutants (HAP). This formulation chemistry evolved functionally as a way to form a "good" coating. Solvents act to provide good flow and wetability of the substrate and they allow intimate mixing of components to insure homogeniety and good crosslinking. In addition, solvent evaporation allows leveling and eventual curing. All of these factors contribute to the formation of a good coating. Environmental regulations are now forcing paint materials and processing technology to move away from the use of formulation chemistries involving VOCs, HAPs, and chromates. Eventually, these ingredients will be substantially reduced or eliminated entirely from the paint technology base. As the formulation technology has moved toward compliance, the use of available, environmentally compliant coatings systems has led to less than satisfactory performance. Adhesion, coating durability, weathering, etc. have suffered. Current low VOC coatings also require much tighter control of the application process parameters and conditions than did the previous high VOC coatings. These conditions have often required the DoD to re-coat systems prior to programmed maintenance leading to significant expenses in the reapplication of coatings.

As the mechanisms of degradation are identified, accelerated test methods and life prediction models must be developed. Much effort is needed in the development of advanced test methodologies/approaches based on fundamental understanding of coating degradation. The expected payoff for this work will be a reduced frequency of paint/depaint operations leading to cost savings, reduced environmental pollution and better maintenance planning. This is a prerequisite for long coating system life and the achievement of true condition based maintenance.

STATEMENT OF NEED FOR FY 99 SERDP POLLUTION PREVENTION NEW START

NONDESTRUCTIVE EVALUATION OF CRACKING AND CORROSION UNDER COATINGS

OBJECTIVE: The objective of this program is to develop nondestructive inspection techniques to locate hidden cracks and corrosion on aircraft and ground vehicle surfaces without requiring removal of the coating system. Currently, the need to inspect substrates for corrosion, fatigue cracks and other damage often requires the removal and replacement of the coating system long before its potential service life is achieved. For example, during Programmed Depot Maintenance (PDM), aircraft skin coating systems are often stripped to evaluate the substrate characteristics, not solely because of poor paint performance. If the substrate could be evaluated without damaging an intact coating system, the number of stripping and repainting cycles could be reduced. If this could be achieved, environmental pollution resulting from hazardous paint strippers and volatile organic compounds released into the atmosphere by the continuous cycle of stripping/re-painting would be dramatically reduced. Thus, developing realistic and practical nondestructive inspection (NDI) technologies for "inspection-through-paint" are critically needed if the Department of Defense (DoD) is to: 1) successfully extend the service life of coatings systems, 2) extend the life of aging weapon systems, 3) meet increasingly stringent environmental requirements, and 4) increase operational capability with limited assets.

BACKGROUND: Historically, materials and processing technology for organic coatings has been based on a formulation chemistry involving extensive utilization of volatile organic compounds (VOCs) and hazardous air pollutants (HAP). Environmental regulations are limiting emissions of VOCs and HAPs and DoD efforts to attain compliance have identified removal and reapplication of coatings as major contributors to the emissions problems at DoD facilities.

Several methods have been analyzed and tested including superconducting quantum interference devices (SQUIDs), infrared imaging, eddy current, self inspecting corrosion sensitive paint systems and ultrasonic methods. Many of these methods have severe constraints that would limit their utility or cost effective application to aircraft systems. Therefore, a new approach must be taken that will take into account both the technical and economic aspects of an inspection technology that detects and quantifies subsurface corrosion damage in military systems.

Satisfactory methods for detecting corrosion through paint do not now exist, although there are some promising approaches, especially for underfilm detection of corrosion and fatigue damage. Other technologies are now being evaluated. Recent military and independent commercial innovation in this regard show some near-term promise. Some of the commercial research includes adding special chemicals to the original paint formulations, which would allow inspection through the paint, or derivations of eddy current or microwave techniques to uncover corrosion. Many of these appear promising and warrant added research and evaluation. Thus, fundamental research and directed research are needed on novel "through-the-paint" inspection methods.

STATEMENT OF NEED FOR FY99 SERDP POLLUTION PREVENTION NEW START

CLEANING VERIFICATION TECHNIQUES

OBJECTIVE: The focus of this program is the development of surface cleanliness analysis technologies. These may include the development of new or the modification of existing equipment, technology or procedures. The new technique(s) should be able to: (1) operate in real-time, such that it is useful in process monitoring and control; (2) provide qualitative and quantitative output for comparative assessment of cleanliness levels (both quantitative amounts and species present); (3) handle a wide variety of military specific applications, such as repair and remanufacturing processes at repair depots; and (4) measure cleanliness levels such that they can be related to required materials property requirements for various surface preparation processes (e.g. repair or application of protective coatings) . Development of cleaning criteria, that is "how clean is clean," for specific weapon systems' components will not be an objective of this program.

BACKGROUND: Many recent research and development projects have focused on identifying substitutes for hazardous materials used in cleaning operations and reducing their overall usage. A common problem encountered in this type of work is that little is generally known about the level of cleanliness attained by these materials and operations. Materials and processes have often been selected through a trial and error procedure. In addition, the level of cleanliness actually necessary for a particular post-cleaning operation is seldom known. Further complicating this issue is the fact that acceptable contamination levels may not only be process specific, but would likely be contaminant specific as well. For example, a bonding application may require a different level of cleanliness than a coating application, and a bonded surface may tolerate a different level of petroleum oil contamination than silicone oil contamination.

Most industrial processes do not currently have in-process cleaning verification technologies in place. Few reliable technologies have been developed, and those that have been are very specialized. Typically, highly variable, non-quantitative approaches are used to determine cleanliness levels, such as water-break tests. If quantitative data is needed, selected parts are sent off line for laboratory analysis, with long turn-around times typical for the analysis.

The availability of a convenient method for analysis of surface contamination that can be used on a wide variety of substrates will enable the user to establish qualitative and quantitative surface cleanliness requirements for specific applications. Once these are established, an immediate determination could be made as to whether an adequately cleaned surface has been attained for subsequent processing. By allowing us to tailor the cleaning process to the cleanliness levels required, it will make possible the use of alternative cleaners and cleaning processes to reduce or eliminate the use of hazardous air pollutants. In the case of some applications, it may even be determined that a cleaning step is not really necessary, as has been found in certain "no-clean" applications in the electronics industry. Finally, real-time monitoring of a cleaning process will reduce the incidence of defects resulting from inadequately prepared surfaces.

STATEMENT OF NEED FOR FY99 SERDP POLLUTION PREVENTION NEW START

ELIMINATION OF HIGH VOC PRIMERS USED WITH RTV SEALANTS

OBJECTIVE: The purpose of this program is develop and/or identify innovative candidates for volatile organic compound (VOC) compliant primers for use with room temperature vulcanizing (RTV) silicone sealants and/or a primerless RTV silicone. Ideally, the new materials will be a drop-in replacement for the current high VOC primers. Successful candidates must meet minimum performance requirements in the following key areas: environmental; toxicology; and physical property performance and materials compatibility as generally required by MIL-A-46106, MIL-A-46146 and AMS 3375. These requirements may be met with either a VOC compliant primer that can be used with current RTVs or a primerless RTV (preferred). Optimum candidates will be subjected by the proposer to all tests necessary to qualify for use on military vehicles under current specifications and samples will be submitted for subsequent field tests.

BACKGROUND: RTV silicones are used extensively for military, aerospace, electronics and high technology applications because of their unique and outstanding material properties. These properties include stability over a wide temperature range (-85F to +500F), excellent electrical insulation properties including outstanding dielectric strength, chemical stability and extreme weather resistance.

However, RTV silicones do have their shortcomings especially when used on metal surfaces. RTV silicones require the use of a primer or prime coat applied to the substrate prior to silicone application in order to develop maximum adhesion. These primers are designed to improve adhesion of RTV silicones to different substrates. They are dilute solutions of moisture-reactive materials that can be used when improved adhesion of RTV silicones for each type of substrate. The choice of a prime coat (of which there are numerous) will depend on the substrate and RTV silicone product used.

All primers and prime coats for RTV silicones contain large amounts of solvents, most of which contain high VOC levels. The primers are applied by wiping or spraying the surface on which the RTV silicone will be applied. The solvent is allowed to "flash" (evaporate), and the active ingredient reacts with moisture in the atmosphere to hydrolyze and develop reactive sites for the RTV to adhere/bond. The various solvents contained in the primers, especially toluene, are subject to numerous regulations such as AB1803 Well Monitoring Chemicals, SARA 313 Toxic Release Inventory Chemicals, AB2588 Air Toxic Hot Spots and others.

STATEMENT OF NEED FOR FY99 SERDP POLLUTION PREVENTION NEW START

VOC COMPLIANT NON-STRUCTURAL ADHESIVES

OBJECTIVE: The focus of this program is develop and/or identify innovative low/no-volatile organic compound (VOC), non-structural adhesives to substitute for the current high VOC non-structural adhesives used in military applications. Non-VOC containing materials are preferred over VOC compliant materials. Successful candidates must meet minimum performance requirements in the following key areas: environmental; toxicology; physical property performance; and materials compatibility as generally required by MMM-A-121, A-A-1936, MMM-A-139, MMM-A-1058, MMM-A-1617 and MIL-A-5540. Optimum candidates will be subjected by the proposer to all tests necessary to qualify for use on military vehicles under current specifications and submitted for subsequent field tests.

BACKGROUND: On September 1, 1995, the "National Emission Standards for Hazardous Air Pollutants of Source Categories: Aerospace Manufacturing and Rework Facilities" became effective. Solventborne adhesive use presents a serious problem that impacts worker health and safety as well as the environment. It has resulted in increased costs associated with hazardous material management including permits and installation of sophisticated emission control equipment. Solventborne adhesives used in "nonstructural" applications, as a class, represent the largest percentage of adhesive bonding performed by U.S. commercial industry (roughly 80-85%). These materials are also used extensively by government contractors, the Department of Defense Services, National Aeronautics and Space Administration, and the Department of Energy Nuclear Weapons Complex to assemble and seal hardware and systems during original manufacture, maintenance and refurbishment. While the quantity used for any one particular application may in some cases be small, the number of different applications numbers in the thousands, including air (and space) vehicles, ships, missiles, soldier systems, building construction, packaging, armaments, munitions, ground vehicles, medical devices and electrical components.

Solventborne adhesives may be one- or two-component systems, often containing 75% (or higher) solvent by weight which is emitted during drying. The most prevalent of these systems are the elastomeric types, including natural rubber, polychloroprene, nitrile and some urethanes as well as reclaimed or other synthetic rubbers. Many of these materials cure ("dry") at ambient temperatures; some nitrile-based adhesives require elevated temperature (i.e. 300°F) cures for applications such as brake linings. In other high-temperature applications, solventborne phenolics are specified. Solventborne adhesives offer many advantages including greater open or "green" tack, superior wettability (especially on unprepared substrates) and the creation of strong bonds that can withstand heat, water, oils and many solvents. In high-volume production applications, these materials are very attractive: they dry fast and require less airflow, and the presence of the solvent tends to reduce or eliminate particle buildup on application equipment. In order to obtain optimal results, solventborne primer systems or adhesion promoters must often be used in conjunction with the adhesives. For example, this is true for the preparation of metal, glass, plastic, and asphalt surfaces for subsequent "nonstructural" bonding with natural or synthetic rubber-based adhesives, including silicones, nitriles and urethanes as well as epoxy, methacrylate and acrylic-based adhesive systems (primers for silicones are addressed above).

STATEMENT OF NEED FOR FY99 SERDP POLLUTION PREVENTION NEW START

MECHANISMS OF CHROMATE CORROSION PROTECTION

OBJECTIVE: The objective of this program is to acquire a fundamental understanding of the chemical and/or physical processes and mechanisms of corrosion protection that occur when chromate-based coatings are applied on metal surfaces. The use of chromates as corrosion inhibitors has evolved empirically over several decades, however, a molecular level understanding of the chemical/physical mechanism(s) by which they operate has never been attained. Not only is it unclear exactly what role chromates play, it is not known what chromate replacement complexes need to do to ensure long-lived coating systems.

BACKGROUND: Historically, protective coatings and surface treatments have been used to provide corrosion protection to Department of Defense (DoD) weapon systems. Current corrosion inhibitor paint chemistry for aluminum relies on the extensive use of metals (such as Cr^{+6} in the form of strontium chromate), which are incorporated into both the surface pretreatment and the primers as highly effective corrosion inhibitor additives. Environmental regulations are forcing paint materials and processing technology to move away from the use of formulation chemistries involving volatile organic compounds, hazardous air pollutants, and chromates, and these ingredients will soon be substantially reduced or eliminated from the paint technology base. As the formulation technology has moved toward compliance, the use of available environmentally compliant coatings systems has led to less than satisfactory performance. Adhesion, coating durability, weathering, and corrosion protection have suffered.

In aerospace applications, corrosion prevention chemistry relies on hexavalent chromates as the corrosion inhibitor for aluminum. NESHAP/EPA 17 requirements are reducing the amount of chromate allowed in surface treatments and primers while Occupational Safety and Health Administration (OSHA) regulations drastically reduce exposure limits to chromates for employees involved in the coating application process. OSHA regulations will result in a practical elimination of chromate usage because of the expense of the employee protection apparatus required. Routine coating maintenance activities such as repair, removal of access panels, and sanding would require protective air handling and employee protection which would not be practical in a hanger site. To meet corrosion protection performance requirements in the DoD, identification of alternatives to chromates must be based on a clear understanding of the corrosion inhibiting mechanism. The new inhibitor chemistry must be incorporated into environmentally compliant surface treatments and coatings. Presently, there are no known acceptable alternatives to chromates as corrosion inhibitors. None of the materials currently under investigation seem to work as well as chromates. In order to meet DoD coating requirements beyond the year 2000 in terms of environmental compliance, and to achieve even modest performance, in terms of durability and corrosion protection, substantial advances in the current state-of-the-art must be undertaken.

APPENDIX F
LIST OF ACRONYMS

A/C	Aircraft
AAP	Army Ammunition Plant
ACA	Air Compliance Advisor
ADN	Ammonium Dinitramide
ADPA	American Defense Preparedness Association
AEC	Army Environmental Center
AEMSS	Advanced Enclosed Mast/Sensor System
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AFCESA	Air Force Civil Engineering Support Activity
AFM	Atomic Force Microscopy
AFOSR	Air Force Office of Scientific Research
AFRL	Air Force Research Laboratory
AFRL/EQ	Air Force Research Laboratory/Environmental Quality
AFRL/MLQ	Air Force Research Laboratory/Materials Laboratory
AH	Attack Helicopter
AHPC	Army High-Performance Computing
AICUZ	Air-Installation Compatible Use Zone
Al	Aluminum
ALC	Air Logistics Center
AMS	Aerospace Materials Specifications
ANL	Argonne National Laboratory
ANM	Animal Noise Monitor
ANSI	American National Standards Institute
AOP	Advanced Oxidation Process
AQMD	Air Quality Management Districts
ARA	Applied Research Associates
ARDEC	Army Armaments Research, Development & Engineering Center
AREP	Alternative Refrigerant Evaluation Program
ARL	Army Research Laboratory
ARM	Atmospheric Radiation Measurement
ARPA	Advanced Research Projects Agency
ARS	Agriculture Research Service
ARSAP	Atmospheric Remote Sensing and Assessment Program
ASAN	Assessment System for Aircraft Noise
ASTE	Advanced Strategic and Tactical Expendables
ASTM	American Society for Testing and Materials
ATD	Advanced Technology Demonstration

ATEDS	Advanced Technology Expendables and Dispenser System
ATLAS	Advanced Testing Line for Actinide Separations
ATOC	Acoustic Thermometry of Ocean Climate
ATOFMS	Aerosol Time of Flight Mass Spectrometer
ATR	Automated Target Recognition
ATRP	Automatic Target Recognition Processor
ATTACC	Army Training and Testing Area Carrying Capacity
BAA	Broad Agency Announcement
BDC	Background Data Center
BDK	Batch Design Kit
BLM	Bureau of Land Management
BOD	Biological Oxygen Demand
BOQ	Bachelor Officers Quarters
BRAC	Base Realignment and Closure
BSAA	Boric-Sulfuric Acid Anodizing
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
C3P2	Cleanup, Compliance, Conservation, Pollution Prevention
CAA	Chromic Acid Anodizing
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CAME	Clean Agile Manufacturing of Energetics
CARB	California Air Resources Board
CARC	Chemical Agent Resistant Coating
CART	Cloud and Radiation Testbed
CATS	Controlled Archeological Test Site
CAV	Composite Armored Vehicle
CBC	Construction Battalion Center
CCAC	Close Combat Armament Center
CCAD	Corpus Christi Army Depot
CCC	Chromate Conversion Coatings
CCD	Charge Coupled Devices
Cd	Cadmium
CDI	Capacitive Deionization
CE	Civil Engineering
CEMS	Continuous Emissions Monitoring System
CER	Center for Environmental Research
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (called Superfund)
CERL	U.S. Army Construction Engineering Research Laboratory
CFC	Chlorofluorocarbon
CFD	Computational Fluid Dynamics
CHPPM	Center for Health Promotion and Preventive Medicine

CHSSI	Common High-Performance Scalable Software Initiative
CIA	Central Intelligence Agency
CL-20	Hexanthrohexaazaisowurtzitane
CMS	Cylindrical Magnetron Sputtering
CNO	Chief of Naval Operations
COTS	Commercial-off-the-Shelf
CPAT	Corrosion Prevention Advisory Teams
CPC	Corrosion Prevention Compound
CPT	Cone Penetrometer
Cr	Chromium/Chromates
CRADA	Cooperative Research and Development Agreement
CRREL	U.S. Army Cold Region Research and Engineering Laboratory
CTC	Control Technology Center
CTIO	Coatings Technology Integration Office
Cu	Copper
CUSP	Commander, Undersea Surveillance Pacific
CW	Continuous Wave
CWA	Clean Water Act
DAF	DNA Amplification Fingerprint
DALM	Diazoluminomelanin
DARPA	Defense Advanced Research Projects Agency
DC	Direct Current
DCA	Dynamic Contact Angle Analyzer
DCA	Dichloroethane
DCE	Dichloroethylene
DECIM	Defense Environmental Corporate Information Management
DEM/VAL	Demonstration/Validation
DENREC	Delaware Department of Natural Resources and Environmental Control
DERA	Defense Environmental Restoration Account
DESCIM	Defense Environmental Security Corporate Information Management
DFA	Difluoroamino
DFSS	Dedicated Feedstock Supply Systems
DMA	Differential Mobility Analyzers
DMMF	Developmental Manufacturing and Modification Facility
DMMP	Dimethylmethylphosphonate
DNA	Defense Nuclear Agency
DNAPL	Dense Non-Aqueous Phase Liquid
DNB	Dinitrobenzene
DNL	Dry Low NO_x
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DPG	Dugway Proving Ground

DRE	Destruction and Removal Efficiency
DUECC	Defense Utility Energy Coordinating Council
DUSD(ES)	Deputy Under Secretary of Defense for Environmental Security
EA	Environmental Assessment
EAM	Effective Area Model
ECIP	Energy Conservation Investment Program
ECU	Environmental Control Unit
EDYS	Ecological Dynamics Simulation
EIS	Environmental Impact Statement
EM	Electromagnetic
EM	Environmental Management
EMAA	Encapsulated Micron Aerosol Agents
EMAP	Environmental Monitoring and Assessment Program
EO	Electro-Optic
EO	Executive Order
EOS	Earth Observing System
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right to Know Act
EPRI	Electric Power Research Institute
EQT	Environmental Quality Technology Program
ERAP	Environmental Risk Assessment Program
ERDEC	U.S. Army Edgewood Research, Development and Engineering Center
ERPM	Emission Reduction Planning Model
ES	Enviroene (EPA Information Umbrella)
ESA	Endangered Species Act
ESMB	Explosive Standoff Minefield Breecher
ESTCP	Environmental Security Technology Certification Program
EXCEL	Experimental Chloride Extraction Line
FAA	Federal Aviation Administration
FDS	Fixed Distributed Systems
FEDS	Federal Energy Decision Screening Model
FEMP	Federal Energy Management Program
FFCA	Federal Facilities Compliance Act
FIC	Fluoroiodocarbon
FID	Free-Induction Decay
FORS	Fiber Optic Raman Sensor
FOX	Fluoroalkoxymethyl-3methyl-Oxetane
FPD	Freezing Point Depressant
FTS	Fourier Transform Spectrometer
FUDS	Formerly Used Defense Sites
FWPPCA	Federal Water Pollution Prevention and Control Act

GAC	Granular Activated Carbon
GC	Gas Chromatography
GCDIS	Global Change Distributed Information System
GC/FID	Gas Chromatography/Free Induction Decay
GC/MS	Gas Chromatography/Mass Spectrometry
GEM	Navy Green Energetics Manufacturing Program
GIMI	Global Imagery Monitor of the Ionosphere
GIS	Geographic Information System
GISS	Goddard Institute for Space Studies
GMS	Groundwater Modeling System
GOCO	Government-Owned/Contractor-Operated
GOES	Geostationary Operational Environmental Satellites
GPR	Ground-Penetrating Radar
GPS	Global Positioning System
GRASS-PRISM	Geographic Resource Analysis Support System - Planning and Resource Integration Stewardship Model
GRFL	Groundwater Remediation Field Laboratory
GSE	Ground Support Equipment
GUI	Graphical User Interface
GV	Grassland Value Function
GWP	Global Warming Potential
HAP	Hazardous Air Pollutant
HAZMAT	Hazardous Materials
HAZMIN	Hazardous Waste Minimization
HBNQ	High-Bulk-Density Nitroguanidine
HCFC	Hydrochlorofluorocarbon
HF	Hydrogen Fluoride
HFC	Hydrofluorocarbon
HMT	High Mesa Technologies
HMX	Octahydro-1,3,5,7-Tetranitro 1,3,5,7-Tetrazocine
HOPS	Heuristic Optimized Processing Systems
HPLC	High Performance Liquid Chromatography
HSRC	Hazardous Substance Research Center
HSSDS	Hazardous Solvent Substitution Data System
HUD	Department of Housing and Urban Development
HVLP	High Volume Low Pressure
HVTS	High Velocity Thermal Spray
HW	Hazardous Wastes
HWRC	Hazardous Waste Research Center
IBEAM	Installation Baseline Energy Analysis Model
ICA	Incremental Cost Analysis
ICAO	International Civil Aviation Organization

ICUZ	Installation Compatible Use Zone
IDIF	Integrated Diffuser, Injector, Flameholder
IDLAMS	Integrated Dynamic Landscape Analysis and Modeling System
IHPTET	Integrated High Performance Turbine Engine Technology
INEL	Idaho National Engineering Laboratory
IPD	Integrated Product Development
IPM	Integrated Pest Management
IPPD	Integrated Product/Process Development
IPT	Integrated Product Team
IR	Infra-red
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
ISCT	In-Situ Chemical Treatment
IUSS	Integrated Undersea Surveillance System
IVD	Ion Vapor Deposition
IWTP	Industrial Waste Treatment Plants
JATO	Jet Assisted Take Off
JDEP	Joint Depot Environmental Panel
JEMP	Joint Engineers Management Panel
JETC	Jet Engine Test Cell
JGAPP	Joint Group for Acquisition Pollution Prevention
JHU/APL	John Hopkins University Applied Physics Laboratory
JPG	Jefferson Proving Ground
JPL	Jet Propulsion Laboratory
LAAP	Louisiana Army Ammunition Plant
LAMS	Laser Ablation Mass Spectroscopy
LANL	Los Alamos National Laboratory
LCA	Life Cycle Assessment
LCAAP	Lake City Army Ammunition Plant
LCAD	Life Cycle Assessment and Design
LCED	Life Cycle Engineering and Design
LCI	Life Cycle Inventory
LCO_2	Liquid CO_2
LFA SURTASS	Low Frequency Active Surveillance Towed Array Sonar Systems
LHM	Lead-Based Paint Hazard Management System
LIBS	Laser-Induced Breakdown Spectroscopy
LIF	Laser-Induced Fluorescence
LIN	Liquid Nitrogen
LIS	Laser Ignition System
LLNL	Lawrence Livermore National Laboratory
LMS	Lead Hazard Mitigation Management System
LNAPL	Light Non-Aqueous Phase Liquid

LOVA	Low Vulnerability Ammunition
LRS&T	Long Range Science and Technology Program
M&S	Modeling and Simulation
MADOM	Magnetic and Acoustic Detection of Mines
MAJCOM	Major Commands
MALDI	Matrix Assisted Laser Desorption Ionization
MAOP	Mobile Meteorological Observation Platform
MARPOL	International Maritime Organizations Marine Pollution Convention
MARS	Mobile Analytical Reconnaissance System
MAS	Millimeter-Wave Atmospheric Sounder
MB/MS	Molecular Beam/Mass Spectrometric
MBT	Membrane BioTreatment
MCB	Marine Corp Base
MCFC	Molten Carbonate
MCRA	Material/Chemical Risk Assessment
MDA-E	McDonnell-Douglas Aerospace-East
MECL	Methylene Chloride
MEK	Methyl Ethyl Ketone
MFR	Monthly Financial Reporting
MIBK	Methyl Isobutyl
MIC	Metastable Interstitial Composites
MIDAS	Munitions Items Disposal Action System
MIPR	Military Interagency Purchase Request
MIT	Massachusetts Institute of Technology
MM	Modifier Molecules
MMATS	Marine Mammal Acoustic Tracking System
MMMS	Mobile Meteorological Measurement System
MMPA	Marine Mammals Protection Act
MMRP	Marine Mammal Research Program
Mn	Manganese
MODIS	Moderate-Resolution Imaging Spectroradiometer
MOI	Multiorifice Impactors
MPC	Mobile Power Center
MR/H	Mine Reconnaissance/Hunter
MRTFB	Major Range and Test Facility Base
MT3D	Modular Transport in 3D
MTADS	Multi-Sensor Towed Array Detector System
MTR	Military Training Routes
MTV	Magnesium-Teflon-Viton
MUDSS	Mobile Underwater Debris Survey System
MWCO	Molecular Weight Cutoff
MWOs	Modification Work Orders

NAAQS	National Ambient Air Quality Standards
NADEP	Naval Depots
NAGPRA	Native American Grave Protection and Repatriation Act
NAPL	Non-Aqueous Phase Liquid
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVSEA	Naval Sea Systems Command
NAX	Natural Attenuation of Explosives
NBS	National Biological Survey
NC	Nitrocellulose
NCAR	National Center for Atmospheric Research
NCBC	Navy Construction Battalion Center
NCIBRD	National Center for Integrated Bioremediation Research and Development
NCMS	National Center for Manufacturing Sciences
NDCEE	National Defense Center for Environmental Excellence
NDFT	Non-local Density Functional Theory
NDI	Nondestructive Inspection
NDI	Non-Developmental Item
NEETC	National Environmental Education and Training Center
NEPA	National Environmental Policy Act
NERL	National Exposure Research Laboratory
NESHAP	National Emission Standard for Hazardous Air Pollution
NETTS	National Environmental Technology Test Sites
NFESC	Naval Facilities Engineering Services Center
NG	Nitroguanidine
NGB	National Guard Bureau
NGP	Next Generation Fire Suppression Technology Program
NHPA	National Historic Preservation Act
Ni	Nickel
NIST	National Institute of Standards and Technology
NMERI	New Mexico Engineering Research Institute
NMFS	National Marine Fisheries Service
NMP	N-Methyl-Pyrolidone
NMR	Nuclear Magnetic Resonance
NOAA	National Oceanic and Atmospheric Administration
NOV	Notice of Violation
NOx	Nitrogen Oxide
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NQ	Nitroguanidine
NRaD	Naval Research and Development Center
NRC	National Research Council
NRHP	National Register of Historic Places
NRL	Naval Research Laboratory

NRMRL	National Risk Management Research Laboratory
NSPS	New Source Performance Standards
NSWC	Naval Surface Warfare Center
NSWC-IHD	Naval Surface Warfare Center - Indian Head Division
NTIS	National Technical Information Service
NTP	Non-Thermal Plasma
NUFT3D	Non-Isothermal Unsaturated/Saturated F&T in 3D
OB/OD	Open Burning/Open Detonation
OC-ALC	Oklahoma City Air Logistics Center
ODC	Ozone Depleting Chemicals
ODOBi	High Explosive Capacity Facility for Open Burning/Open Detonation Testing
ODP	Ozone Depleting Potential
ODS	Ozone Depleting Substances
ODUSD(ES)	Office of the Deputy Under Secretary of Defense for Environmental Security
OEM	Original Equipment Manufacturer
OEW	Ordnance Explosive Wastes
ONI	Office of Naval Intelligence
ONR	Office of Naval Research
OPC	Optical Particle Counters
OPNAV	Naval Operations, Headquarters Staff (Pentagon)
OPNAVINST	Naval Operations Instruction
OS3D	Operator Splitting in 3D
OSHA	Occupational Safety and Health Administration
OTD	Office of Technology Development
OWS	Oil/Water Separators
PAA	Phosphoric Acid Anodize
PAFC	Phosphoric Acid Fuel Cells
PAH	Polycyclic Aromatic Hydrocarbon
Pb	Lead
PBPK	Physiologically-Based Pharmacokinetic
PCA	Tetrachloroethane
PCB	Polychlorinated Biphenyls
PCE	Perchloroethylene (tetrachloroethylene)
PCR	Polymerase Chain Reaction
PDM	Programmed Depot Maintenance
PED	Photoelectric PAH Detector
PEO	Program Executive Officer
PEO/FAS	Program Executive Officer for Field Artillery Systems
PEP	Propellants, Explosives, Pyrotechnics
PG	Propylene Glycol
PI	Principal Investigator
PM	Particulate Matter

PM	Program Manager
PMB	Plastic Media Blasting
PMC	Polymer-Matrix Composite
PNL	Pacific Northwest Laboratory
POAM	Polar Ozone and Aerosol Monitor
POL	Petroleum, Oil, Lubricants
PP	Pollution Prevention Thrust Area
PTFE	Polytetrafluoroethylene
PTT	Platform Transmitter Terminals
PVD	Physical Vapor Deposition
QA/QC	Quality Assurance/Quality Control
QMP	Quality Management Plan
QSAR	Quantitative Structural Activation Reaction
R&D	Research and Development
RACER	Remedial Action Cost Engineering and Requirements
RAIDS	Remote Atmospheric and Ionospheric Detection System
RASS	Radio Acoustic Sounding System
RBCA	Risk-Based Corrective Action
RCI	Rapid Commercialization Initiative
RCRA	Resource Conservation and Recovery Act
RCW	Red-Cockaded Woodpecker
RDEMS	Relational Database Management System
RDT&E	Research, Development Test & Evaluation
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
REEP	Renewable and Energy Efficiency Planning
RfD	Reference Dose
RMA	Rocky Mountain Arsenal
ROD	Record of Decision
RREL-EPA	Risk Reduction Engineering Laboratory - Environmental Protection Agency
RSKERL	Robert S. Kerr Environmental Research Laboratory
RTDF	Remediation Technologies Development Forum
RTG	Room Temperature Gradiometer
RTV	Room Temperature Vulcanizing
RUSLE	Revised Universal Soil Loss Equation
S&T	Science and Technology
S-O&CS	Smokes, Obscurants & Chemical Simulant Agents
SAB	Scientific Advisory Board
SAE	Society of Automotive Engineers
SAGE	Solvent Alternatives Guide
SANS	Small Angle Neutron Scattering
SAPT	Symmetry Adapted Perturbation Theory

SAR	Structural Activity Relationships
SAR	Synthetic Aperture Radar
SBAA	Sulfuric-Boric Acid Anodize
SBIR	Small Business Innovation Research
SCAMP	Subsurface Cleanup and Mobilization Processes
SCAPS	Site Characterization and Analysis Penetrometer System
SCF	Supercritical Fluid
SCR	Selective Catalytic Reduction
SCWO	Supercritical Water Oxidation
SDI	Strategic Defense Initiative
SEAM3D	Sequential Electron Acceptor Model in 3D
SEM	Scanning Electron Microscope
SEMP	SERDP Ecosystem Management Program
SERDP	Strategic Environmental Research and Development Program
SERS	Surface Enhanced Raman Sensor
SF	Supercritical Fluid
SFC	Specific Fuel Consumption
SFE	Supercritical Fluid Extraction
SHDS	Solvent Handbook Data System
SIFDT	Selected Ion Flow-Drift Tube
SIMWE	Simulated Water Erosion
SMCA	Single Manager for Conventional Ammunition
Sn	Tin
SNAP	Significant New Alternatives Policy
SNL	Sandia National Laboratory
SNRM	Strategic Natural Resources Management
SO_2	Sulfur Dioxide
SODS	Seismic Ordnance Detection System
SOFAR	Deep Sound Conducting Channel
SON	Statement Of Need
SOP	Standard Operating Procedure
SOSUS	Sound Surveillance System
SOTA	State-Of-The-Art
SQUID	Superconducting Quantum Interference Device
SRS	Savannah River Site
SRTC	Savannah River Technology Center
STR	Synthetic Tandem Repeat
SVE	Soil Vapor Extraction
SW	Shallow Water
TAMU	Texas A&M University
TAP	Technical Advisory Panel
TARA	DoD Environmental Technology Area Review & Assessment
TCA	Trichloroethane

TCE	Trichloroethylene
TCLP	Toxicity Characteristic Leachate Procedure
TDL	Tunable Diode Laser
TDP	Technology Development Plan
TDS	Total Dissolved Solids
TES	Threatened and Endangered Species
TET	Tetryl
TETAT	Technology Education and Training Advisory Taskforce
Tg	Transition Temperature
TIPPP	Tidewater Interagency Pollution Prevention Program
TIWET	The Institute for Wildlife and Environmental Toxicology
TL	Transmission Loss
TLM	Test Location Manager
TNAZ	1,3,3-Trinitroazetidine
TNB	Trinitrobenzene
TNT	Trinitrotoluene
TPE	Thermoplastic Elastomer
TRI	Toxic Release Inventory
TRU	Transuranic Radioactive Waste
TSVP	Thermal Spray Vitrification Process
TTAWG	Technology Thrust Area Working Group
TV	Trapped Vortex
TVC	Trapped Vortex Combustor
UARS	Unmanned Air Reconnaissance System
UAV	Unmanned Aerospace Vehicle
UB	Ultra Broadband
UFA	Unsaturated Flow Apparatus
UFAL	Ultra-Fine Aluminum
UHC	Unburned Hydrocarbons
UM	University of Minnesota
USACE	United States Army Corps of Engineers
USACERL	U.S. Army Corps of Engineers, Construction Engineering Research Laboratories
USDA	United States Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGCRP	U.S. Global Change Research Program
USGS	U.S. Geological Survey
USPED	Unit Stream Power Erosion/Deposition
UST	Underground Storage Tank
UVRS	Ultraviolet Remote Sensing
UWB	Ultra Wide Band
UXO	Unexploded Ordnance

VAAP	Volunteer Army Ammunition Plant
VARTM	Vacuum-Assisted Resin Transfer Molding
VLA	Vertical Line Arrays
VNTR	Variable Number of Tandem Repeats
VOC	Volatile Organic Compound
VPI	Virginia Polytechnic Institute and State University
WEPP	Water Erosion Prediction Project
WES	U.S. Army Engineer Waterways Experiment Station
WHV	Wildlife Habitat Value Function
WIC	Water-Injection Controller
WR	Water Reducible
WS	Weapon Systems
WWW	World Wide Web
XAS	X-ray Absorption Spectroscopy
XCRIS	X-windows-based Cultural Resource Information System
XPS	X-ray Photo-Electron Spectroscopy
XRD	X-ray Diffraction
XRF	X-ray Fluorescence
XRS	X-ray Spectrometry
YP	Yard Patrol
Zn	Zinc

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